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THE NATION'S FORESTS. 1. THE FOREST OF DEAN

BY WILLIAM LING TAYLOR

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THE Forest of Dean lies in the triangle formed by the lower reaches of the rivers Severn and Wye in the south-western extremity of the county of Gloucestershire. It represents one of the most important survivals of the

formerly extensive Royal Forests of England, and was part of the ancient hereditary estates of the Crown. No recorded information now exists as to the origin of any of the Royal Forests, though much has, of course, been heard of the eleventh-century activities of William I in connexion with New Forest,

and it can be regarded as probable that the Forest of Dean has been forest land, more or less in the present meaning of the term, from time immemorial. In prehistoric times, before the encroachments of man became serious, no doubt the area formed part of the almost continuous forest which then covered the greater extent of southern Britain. This part of the country appears to have escaped the extreme severities of the last Ice Age, and to have lain just beyond the southern limit of the ice sheet. What conditions actually were in those early days can now only be surmised. The limestone caves of the Wye gorge have yielded traces of very early human occupation, and the usual relics of prehistoric animal life, while the primeval forest may have been populated with oak, ash, wych elm, hornbeam, alder, birch, cherry, lime, field maple, crab apple, sallow, white beam, mountain ash, hazel, holly, and yew, all of which are regarded as indigenous species in Britain. The last-named is the only conifer, and whether or not *Pinus silvestris* was represented is a matter for speculation. The inference is that the indigenous oaks were sessile.

HISTORICAL OUTLINE.

In a very remote age, man was attracted to the forest by its wealth of minerals, and also in pursuit of game, and there is evidence of a fairly numerous population and considerable activity by the time of the Roman occupation. After the battle of Senlac the Forest of Dean became one of the hunting-grounds of the Norman kings, and in the reign of Henry II its boundaries extended from Gloucester, via Newent, to a point a little south of Ross on the north, and to the confluence of the Severn and the Wye at Chepstow on the south, forming a rough triangle bounded on the east and west by these rivers. Encroachment and deforestation steadily reduced the forest area, as is proved by the records of successive perambulations of the boundaries. By the time of Edward II the area had been reduced by more than half. By the statute 20 Car. II, c. 3 (1668) the Crown was empowered to enclose commonable waste of the forest for the purpose of the growth of timber, provided that the total area enclosed was not at any time to exceed 11,000 acres, and this limit still obtains. The enclosures authorized were to be freed from common rights so long as enclosure continued, and when the trees were grown up beyond damage the areas could again be thrown open for grazing and an equivalent area enclosed elsewhere. The provisions of this statute were re-enacted by 48 Geo. III, c. 72 (1808), and measures were taken to enforce them. The reason for this action was to ensure a supply of oak timber for the Navy. From the days of Charles II until 1808 the total area of the Forest of Dean suffered no appreciable reduction and in the year last mentioned extended to some 18,500 acres, together with between 600 and 700 acres of Crown freeholds.

The modern history of forestry in the Forest of Dean may be considered to begin in 1668 when effect was given to an arrangement with the commoners to enable the Crown to enclose, against their cattle, up to the 11,000 acres prescribed, for the purpose of timber production. The Act of 1668 recited that the wood and timber of the Crown, which of late years had been very great

in quantity and value within the forest, had become totally destroyed, excepting that which was standing within the 'Wardenship of Lea Bayly', so that some course was necessary speedily to be taken to restore and preserve the growth of timber for the supply of the Navy. The full area authorized by the Act was soon afterwards enclosed. In 1675 the forest was divided into six walks or districts; six lodges were built and for each walk a keeper was appointed. It is stated in a return made in 1691 that, except in 'Lea Bayly', where the fences had been thrown down by dissatisfied commoners, the plantations were 'generally very well grown'. Again, in 1705, there is a report extant to the effect that the woods were very full of young trees, two-thirds of which were beech which were overtopping the oaks. By 1788 the actual area remaining enclosed had dwindled to 675 acres. The position was re-established by the statute of 1808, which recited that the Act of 1668 had 'not been duly put in Execution'. The balance necessary to make up the total of 11,000 acres was directed to be enclosed. At this period the rest of the forest was very sparsely covered. It was estimated that 24,000 old oaks remained on the ground, of which large quantities were cut for naval construction. Few of these old oaks are now left, but there are still about a dozen standing in Churchill Enclosure, and a very few others in various parts of the forest. Fellings for the Navy finally ceased in 1863.

EARLY MANAGEMENT AND SILVICULTURE.

Probably the earliest record of any manifestation of interest in the protection of the Forest of Dean on the part of the Crown is contained in the Domesday Book, which states that Edward the Confessor exempted the forest from taxation. The terms used are, *has tras c'cessit rex E. quietas a geldo pro foresta custod.* Under the earlier Norman kings the forest was administered by the Constables of St. Briavels's Castle, who were also Wardens of the Forest of Dean. Wood from the forest was utilized for the smelting of iron, for mining purposes, and for domestic uses, while the rights of pannage were important locally. Later the forest was farmed out from time to time to favourites of the reigning kings. The office of Constable persisted, but the only conclusion is that forest management under this régime was at no period systematic. It may be inferred, however, that the local timber had acquired a reputation for ship-building from the interest taken in the forest by those responsible for the Spanish Armada. Evelyn in his *Silva* mentions that he had heard 'that in the great expedition of 1588 it was expressly enjoined the Spanish Armada that if, when landed, they should not be able to subdue our nation and make good their conquest, they should yet be sure not to leave a tree standing in the Forest of Dean'. As to this, there is also the possibility that it was the iron industry at which it was desired to aim. The drain of timber for the iron-furnaces was such that in the reign of Elizabeth legislation became necessary to protect the timber resources of the nation. From about this period and onwards the history of the forest is one of almost unbroken exploitation and mismanagement by successive court favourites. There was a change of heart

on the part of the Crown in 1638, when a survey made plain the parlous condition and stocking of the woods. Some 17,000 acres were then ordered to be enclosed. The scheme merged, however, into the famous (or infamous) sale of the forest to Sir John Winter by Charles I in 1640. Winter's patent was annulled by the Commonwealth, and during this period very extensive fellings were made and the timber sold for the benefit of the Government. It is at the same time fair to state that in 1656 a Bill was passed for the preservation of the timber in the forest. Reafforestation was, however, fiercely resisted by the inhabitants at this time, and little permanent good seems to have been done. Winter's 'rights' were restored to him by Charles II, greatly to the displeasure of the neighbourhood. At this time a new survey showed that the mature timber in the forest was reduced to 25,929 oaks and 4,204 beeches. In 1667 hardly any trees remained. In the meantime a committee of the House of Commons had been appointed to investigate local complaints, and their report embodied the following proposal: 'Imprimis, That 11,000 acres of the wastle soil of the Forest of Dean, whereof Lea Baily and Canopp to be part of the said wastle, may be enclosed by his Majesty, and discharged for ever from all manner of pasture, estovers and pannage; and if ever his Majesty, or his successors, shall think fit to lay open any part of the said 11,000 acres, when to take in so much elsewhere, so as the whole enclosure exceed not at any one time 11,000 acres.' This proposal formed the basis, as to enclosure, of the statute 20 Car. II, c. 3, already referred to, and this basis of tenure has not since been altered. Hitherto there is much record of exploitation and little of reafforestation, but planting there must have been for a return of 1680 refers to plantations made ten years earlier, and a few years afterwards 'Cannop Fellet, Buckholt, Beachenhurst and Moyey Stock' are described as generally very well grown with oak and beech of fifty, forty, and thirty years' growth and under, many thousands of them being 40 feet and upwards 'without a bough to hurt them', a somewhat strange remark when it is remembered that knees and ships' timber were required. By 1705 the Office of Surveyor General to the Royal Forests had come into being, the holders of which, with their Deputy Surveyors, play a prominent part in the administration of the Forest of Dean from this time onwards. The Office of Surveyor General was later merged into that of the Commissioners of Woods and Forests. A considerable gap in the official record of the forest now ensues, but in a report to the Treasury in 1736 the then Deputy Surveyor indicates that the past thirty years had been yet another period of serious neglect, a state of affairs which continued in varying degree of intensity for the next half-century. In 1788 large tracts of the forest, which can be identified, were bare of timber. In this year yet another of the multitudinous commissions of inquiry led to the appointment of surveyors whose report gives a clear picture of the forest as they saw it. The total area enclosed had shrunk to 3,220 acres. An interesting item in this report records that a few Weymouth pines had been planted in Buckholt Enclosure and that these trees grew well.

The next definitely progressive step was the Act of 1808 (48 Geo. III, c. 72)

already mentioned. From this period also dates the connexion with the forest of Mr. Edward Machen as Deputy Surveyor. This officer left valuable manuscript notes which are freely quoted from by Nicholls in his account of the Forest of Dean. Six Commissioners were appointed under the Act. In 1810 the work was commenced and Barnhill, Serridge, Beechenhurst, and Holly Hill were enclosed. These areas were planted by contract. The agreement was 'to dig holes 15 inches square and 9 inches deep to be planted with sound, healthy acorns at 4 feet apart each way and every tenth hole 18 inches square and 12 inches deep to be planted with sound healthy plants of oak, Spanish chestnut, larch, fir, sycamore, or beech of five years old, three years transplanted, as the various qualities of the land or other circumstances may require, and, in general, throughout the whole with a Spanish chestnut in each hundredth hole'. The oak seedlings were nearly all killed probably by mice and birds, but possibly also by neglect in keeping the young oaks clear of the rough weeds. 1814 is recorded as a 'mouse year' in the district and over one hundred thousand tails were brought in to the Deputy Surveyor. The plantations were filled up by putting in 4-year-old oaks between every tenth tree so that about 600 trees to the acre were actually left to grow. The remaining area to make up 11,000 acres was planted up in a similar way, and by 1816 the task was complete. There were many failures and the woods were not considered to be established until 1832. From 1828 to 1853 no less than £134,244 was received for thinnings, so that the forest, which had not been properly stocked to begin with, was seriously over-thinned and has never recovered up to the present day. It is necessary to bear in mind, however, that the result then aimed at was the production of trees with 'knees' and spreading crowns for naval construction. The Deputy Surveyor's notes (1818) as quoted make interesting reading. Speaking of Buckholt, one of the older enclosures, he observes: 'The large timber in it has been cut, and parts of it planted with young oaks obtained from places where they had sprung up spontaneously, but it is still imperfectly stocked. Stapledge has been filled up by transplanting from the thick parts and is tolerably well stocked on the whole. Birchwood has been planted in the vacant parts and is very flourishing. From the Acorn Patch a large quantity of young oaks have been transplanted into the open parts of the Forest and the upper part of Russell's Enclosure. The trees drawn out are thriving and many of them grow faster than the trees remaining in the Acorn Patch. The trees though never transplanted before, came up with bunches of fibrous roots; and though of so large size, being from 10 to 25 feet high, scarcely any of them failed. Several experiments were tried as to pruning closely, pruning a little and not at all; and it appears that those pruned sufficiently to prevent the wind from loosening the roots answer best, although many of those which were reduced to bare poles, and had their heads cut off, are now sending up vigorous leading shoots and have the appearance of becoming fine timber; those unpruned did not succeed at all.'

At this time 49¼ acres of nursery were maintained and contained about four million oaks and about 600,000 firs and other trees of various sorts. Mention

is made of damage to young plantations by frost in various parts of the forest. On 29 May 1819 frost was so severe that 'the verdure around White Mead and throughout all the low parts of the Forest was entirely destroyed, in short all trees but Scotch fir and poplar suffered severely'. Ellwood (110 acres) was planted in this year. The holes were dug 4 feet apart in rows, and 5 feet between the rows. The trees planted were 30,000 Scots pine, 1,600 maritime pine, 3,600 larch, 6,000 Spanish chestnut, 120,000 3- and 4-year oaks, and 4,500 oak seedlings. This plantation was filled up in the following year (1820) with 15,000 Scots pine, and during the ensuing season no fewer than 1,625,500 oaks and 360,500 firs were planted out to 'mend over' the different enclosures. Another interesting note from the same source reads: 'Although Scotch firs have succeeded so well as nurses to the oaks, and have brought them forward, making them healthy and thriving on land that without shelter would only have produced them stunted and unthrifty yet I am inclined on the whole to prefer larch. . . . In some of our cold valleys, however, larch will not grow, the spring frosts cutting them off.'

Some data concerning the growth of the transplanted oaks in Acorn Patch have been preserved and appear in the following table. The girths are taken at 6 feet from the ground:

	Transplanted at 16 yrs.	*Transplanted at 23 yrs.*	*Not Transplanted at all.*
	inches	inches	inches
14 Sept. 1809 . . .	7⅝	7	11¼
5 Oct. 1814 . . .	14¾	11	15⅝
20 Oct. 1820 . . .	23⅞	19	19⅞
„ 1826 . . .	32⅛	27¼	23
„ 1830 . . .	40½	35¾	26½
„ 1836 . . .	48¾	39½	30
„ 1840 . . .	53¼	42½	32½
„ 1846 . . .	60½	47¾	36½

Throwing open, with some re-enclosing and planting, continued intermittently until 1872, from then until 1896 no more land was enclosed, the total area of the enclosed woods then being only 4,665 acres out of the statutory area of 11,000 acres. The area so enclosed in 1914 was 9,252 acres, and this total has since been raised to within a few acres of the statutory limit.

The Forest of Dean remained under the control of the Office of Woods and Forests until it was transferred to the Forestry Commission in 1924 by Order in Council under the Forestry (Transfer of Woods) Act, 1923.

TENURE.

An outline of the general principles underlying the tenure on which this forest is held has already been made plain. A total of 11,000 acres of the open forest land can be enclosed at one time for the growth of timber, and lands upon which timber crops have been established can be thrown open from

time to time, and an equivalent area of the open forest again enclosed for silvicultural purposes. The forest, however, is subject to the rights of the 'free miners' whose 'customs and franchises' were, even so far back as the reign of Edward I, said to have been granted 'time out of minde'. The free miners have the right to apply for and work the minerals, the unit of area for which purpose is known as the 'gale'. They must, however, compensate for surface damage, and are liable at Common Law for damage by subsidence. The open forest, which includes all forest land not for the time being enclosed, is subject to rights of common, and can be grazed by the commoners, of whom few, if any, survive. Most of the grazing is by sheep, and most of these sheep are owned by persons who have no ancient right of common. Furthermore, sheep are not commonable animals, but they have been pastured in the open forest for so many years past that it is now questionable if the custom can ever be denied. Pigs running on the open forest are required to be ringed.

In addition to the statutory area of 11,000 acres and the open forest land there are some 416 acres of freehold woods in the Forest of Dean proper as well as Abbotswood (623 acres), Hope Wood (191 acres), Chase Wood (202 acres), and the Clearwell Woods (127 acres), which are included for working-plan purposes. The former privileges, as to grazing, firewood, &c., of foresters and Crown woodmen have been commuted.

GEOLOGY AND SOILS.

The central, western, and southern parts of the forest overlie the Coal Measures which form a shallow basin roughly oval in form and about eight miles long from north to south and five miles across. The coal-field stands on beds of Millstone Grit and Limestone which outcrop around the edge of the coal measures. Further outcropping of Old Red Sandstone occurs on parts of the periphery of the forest. The resultant soils are mainly yellowish clay loams and clays over the coal measures with some of lighter texture over the millstone grit and old red outcrops, although on parts of the latter the soils are clayey and heavy. A thin stratum of dark impervious clay, the Woorgreen Bed, also outcrops on the upper slopes of the coal measures, and gives rise to numerous small springs. There is, on the whole, a deficiency of humus due to past mismanagement of the forest, grazing, and fires. Peat occurs only in small patches in some of the wet spots, and generally there is practically no apparent leaching of the surface soils.

PHYSIOGRAPHY.

The configuration of the forest area has been aptly described as a palmate arrangement of four main ridges spreading towards the north. The westerly ridge runs out almost to the edge of the coal basin on that side; the central ridge extends due north, and the two eastern ridges to the outer edge of the forest on the east side. The latter are steep sided on their eastern slopes. Easterly and westerly aspects thus predominate.

There are no large rivers within the forest, and generally the streams run

off to the south-east into the River Severn a few miles after leaving the forest boundary. Much of the water carried by these streams is pumped from the mines, and some fairly extensive artificial ponds have been formed at Cannop and Sutton Bottoms. Drainage is good except on the flatter carboniferous areas, where much open drainage was done in past years.

VEGETATION.

Except in the wettest areas, bracken and bramble are abundant throughout the forest. On the dry slopes the growth of bracken is dense and luxurious. It does not flourish to the same extent towards the centre of the basin, where, although not so tall, it is still dense. Bramble comes into the oak woods wherever sufficient light penetrates. *Holcus mollis* is a feature when soils are moist and *Aira flexuosa* on the drier lands. *Molinia* and *Aira caespitosa* come in wet places. Ling and bilberry occur on the millstone grits, while on the sandstone areas *Luzula* spp. is frequently abundant. The forest flora is, on the whole, neither very extensive nor interesting.

METEOROLOGY.

Rainfall has been recorded in the forest since 1904. The average precipitation is 36·3 inches yearly. Mean monthly temperatures (Fahrenheit) vary from 38° to 61° and the climate is moderately equable, though one of the most trying features is late frost. Snowfall is seldom heavy, but south-west gales can be severe and constitute a danger. Pepys records that an exceptionally severe gale, on 18 February 1662, blew down more than 1,000 oaks and as many beeches in one walk of the forest alone.

PRESENT POSITION AND WORKING PLAN.

From the time the present crop of oak was established, some 100–20 years ago, until 1896 the forest was under no definite working plan. At first cuttings took the form of heavy thinnings throughout the area, and the resultant damage to the existing woods cannot now be remedied. In 1896 a report was made by the late Mr. H. C. Hill, I.F.S., and a start was made to regenerate some the poorer woods. It was at this time deemed wise only to cut small groups and replant with conifers, but experience of the subsequent extensive suppression of these groups led to the other extreme. The remaining oaks were removed, new plantings were preceded by wholesale clear fellings, and in consequence suffered severely from frost. This plan, while it provided for putting some of the worst land under conifers, did not contemplate any extensive conversion to softwoods. Its importance lies in the fact that it stopped the previous system of thinning, and provided for enclosure up to the full area permitted by statute. The turn of the new century brought the first steps towards a National Forest policy, which recognized the necessity of establishing demonstration areas and amplifying supplies of coniferous timber. It was decided to convert 75 per cent. of the Forest of Dean to conifers, and a plan was accordingly drawn up in 1916. The scheme was to convert 190

acres to conifers and to regenerate 40 acres with oak, in each year, in regular felling series with the ultimate aim of a conifer forest of 12,000 acres normally stocked with age classes 1 to 60, and the establishment of an oak forest of 4,000 acres. Lack of markets hindered this scheme, which was not elastic enough for the prevailing local conditions.

The War followed and arising out of its necessities a really vigorous National Forest policy at last came into being on the basis of the Acland Report of 1918. The work of acquiring and planting large areas with softwoods has proceeded apace since the passing of the Forestry Act, 1919, and necessity to devote hardwood soils to conifers no longer obtains. As a corollary, policy in the Forest of Dean has been revised and hardwoods, mainly oak, are prescribed for as much as possible of the area. The past eight years have been spent in developing this policy.

Briefly the present plan is that roughly 11,000 acres have been allotted to hardwood circles, part of which total area consists of land already planted with conifers. This land will be replanted with hardwoods for the subsequent crop. The remaining acreage available is at present still relegated to a conifer circle and will serve as a source of revenue during the years in which the sparsely stocked 1 to 100 age classes come to maturity. One of the factors complicating the problem is that many of the older oak stands are so unhealthy as to render it doubtful if the timber can usefully be retained, even for 30 to 40 years, much less the period needed to maintain a sustained yield while age classes for hardwoods are being adjusted.

The present distribution of age classes is as follows:

Age.	*Hardwoods. Acres.*	*Conifers. Acres.*	*Coppice, &c. Acres.*
0–20 . . .	994	2,885	204
21–40 . . .	671	1,005	—
41–60 . . .	83	18	—
61–80 . . .	1,172	181	—
81–100 . . .	1,371	—	—
101–120 . . .	6,844	—	—
Acres . . .	11,135	4,089	204

There are also blanks and waste included in the Working Plan area amounting to 426 acres, and nurseries which occupy a further 21 acres.

There is considerable abnormality in these age classes, and the state of affairs is complicated by the condition of many of the older oak stands. It may, therefore, be necessary (if oak fellings are further speeded up) to plant conifers with the definite intention of providing catch crops for the adjustment of age classes in the hardwood circle. Flourishing woods, hardwoods and conifers, are found only in age classes 0–20, 21–40, and 61–80. The greater part of the balance contains stands deficient both in volume and increment. The oak has, apart from its bad treatment, been subject to repeated cycles of defoliation by two species of caterpillar, *Cheimatobia brumata* and *Tortrix viridana*. This is

nothing new, because visitations of the leaf-roller are recorded by Machen (Nicholls) in the early part of the past century and seem to have been no new phenomenon then. Here, as elsewhere in the south of England, *Quercus sessiliflora* fares better than *Q. robor* owing to its habit of earlier flushing and tougher leaves. It is fairly evident from continental experience that repeated defoliation with its attendant fungus troubles (*Oidium* and *Armillaria mellea*) must have an adverse effect upon the crop, but it seems that the heart-rot, to which much of the present crop of Dean oak is subject, cannot be laid to the score of the caterpillar. This rot, *Stereum spadicium*, enters the tree by way of the heartwood in the dead branches, themselves the result of the over-thinnings of pre-working-plan days. The incidence of this rot is under investigation. On the whole it is certainly problematic if the older oak can remain for a further 30 or 40 years, and temporary conversion to conifers may be necessary. For this, artificial methods are inevitable and transplants are in general use, there being very little land in the forest suited to the turfing of seedlings.

At present about 700 acres of oak are under natural regeneration, success being dependent upon mast years and the absence of depredations of mice and wild pigeons. The early age classes include 370 acres of oak, naturally regenerated from the mast years of 1900–1 in Blakeney Hill.

There are at the moment 21 acres of nursery ground (18 in use) and considerable quantities of seedlings and transplants are exported. The chief nursery area (12 acres) is at Nagshead. There is also a small pinetum near the Speech House containing some sixty species. This area has been badly retarded by late frosts, and it is of interest that *Cryptomeria japonica* has prospered conspicuously in spite of this drawback.

RISKS AND GENERAL CONDITIONS.

The chief adverse influences against which protective measures are necessary are sheep-trespass, mice and voles, climatic conditions, fires, insects, and fungi. Sheep have been a nuisance over a very long period, and fencing against this form of trespass in the enclosures is one of the most important measures of protection which have to be undertaken. The small rodent population waxes and wanes, and from time to time considerable damage ensues. The forest is remarkably free from rabbits and there are few hares. Wild deer were exterminated in the district many years ago, except for a small herd (fallow) in the neighbouring Highmeadow Woods.

Climatic conditions have already been described. Wind and late frost which occurs well into the month of June are the main troubles with occasional heavy snowfall as on 29 March 1916, when the amount of snowbreak was serious. Fire is an ever-present danger, especially in Beechenhurst and Serridge Enclosures and elsewhere from the railways. With the increase of the area under conifers the fire risk also increases and constant vigilance is necessary. The forest is under a comprehensive fire protection plan with look-out towers connected by telephone.

The usual insect fungous pests are present, the most troublesome of which

are *Armillaria mellea*, *Fomes annosus*, *Stereum spadicium*, *Dasyscypha calycina*, and *Oidium* spp. The insect question and its influence, in conjunction with certain of the fungi, on the growth of oak in the forest is certainly in some measure related to the bird population. Small insectivorous and other birds are scarce, owing, in part at any rate, to the excessive numbers of crows, magpies, and jays. Hawks and owls are also sparsely represented, and one of the most promising measures of protection at the present time, so far as young hardwood plantations and future oak crops are concerned, probably lies in an intelligent attempt to restore the balance of natural bird life within the forest. Smoke and fumes play a greater part than has sometimes been realized. The growth and development of Norway spruce do not give any marked indications of this trouble, and Scots pine, while not generally so healthy, are affected by other factors which render it difficult to assess the effects of smoke. European larch does, however, appear to suffer in several parts of the forest, especially in its early stages. Smoke may also be responsible, to some extent, for the rather erratic behaviour and growth of Douglas fir in this district. The other conifers employed are all more or less smoke resistant.

CHOICE OF SPECIES.

Sessile and pedunculate oak (*Quercus sessiliflora* and *Q. robor*) are the principal broad-leaved trees now prescribed, with some beech, sycamore, and Spanish chestnut; beech is used mainly for underplanting; poplar does not flourish in the forest. Of the conifers, Norway spruce has been planted extensively and succeeds well. Of recent years Sitka spruce is also being made use of. Douglas fir (Oregon) is not consistent, but some of the plantations are most promising; the species has suffered in its early years from *Chermes cooleyi* and frost; it has in some compartments been planted in mixture with Thuya. Corsican pine finds a place on the limestone ridges, and in some of the frosty spots recourse has been made, of necessity, to Scots pine. The larches have been planted freely, and on the whole are progressing satisfactorily, though *Larix decidua* shows indications of smoke damage in some of the plantations. The planting of oak with larch nurses has been discontinued and oak is now planted pure. Weymouth pine is not, of course, now planted, but there are a few old and very fine specimens standing in Buckholt to the north of the Cannop Colliery; the last remainder, perhaps, of those referred to in the report of the surveyors appointed under the Commission of Inquiry, which was set up in 1788, as having been planted there about that date.

INCREMENT AND YIELD.

Unfortunately it is not possible to give accurate figures for increment in the old oak woods. Measurements were taken in the past, but lapsed during the War. In any case owing to the serious 'die-back' in the 100-year age class the value of any figures would be extremely small as it appears that the increment is set off by loss from heart-rot. Further, owing to the heavy thinnings in the past, of which no proper record was kept, it is not possible to prepare increment

tables for the older woods. An estimated average figure for the older oak is 15 cub. ft. per acre per annum.

It is noticeable that the height growth in the present 100-year stands falls off after about the 40th year. In the few areas of younger woods, 20–40 and 60–80 years age classes, the height growth does not cease and the volume compares favourably with best-quality classes in Schwappach's yield tables.

Three examples may be given of present yield: the first is a clear cut of 11 acres made in Russell's Enclosure, which is one of the best of the older oak woods; the second is a clear cut of 15 acres in Oakenhill, one of the poorer stands in which there has been bad die-back, and which is now almost entirely clear cut; and the third is extracted from measurements of a sample plot in Bradley Hill, which is the best of the younger woods.

(*a*) *Russell's. Age about 115 years.*

11 acres oak, 1,000 cub. ft. timber, q.g. measure, T.O.B., 440 cub. ft. of pitwood and cordwood 20 cords, all per acre.

(*b*) *Oakenhill. Age about 130 years.*

15½ acres oak, 825 cub. ft. timber, q.g. T.O.B., 164 cub. ft. of pitwood and cordwood 10 cords, all per acre.

(*c*) *Bradley Hill. Age 55 years.*

Standing volume, T.O.B., 3,293 cub. ft. timber per acre.

UTILIZATION.

Local markets are not very elastic. Saw logs (oak) are disposed of in the round to the Parkend Saw Mills Ltd. and to other timber merchants in the district. Selected beech logs are exported. Pitwood, both conifer and hardwood, finds a ready sale to local dealers for the Dean mines and the South Wales coal-field; cordwood is sold to the Wood Distillery adjacent to Speech House Road railway station, and as firewood and poles (thinnings) of all sorts to various buyers locally and in the Midlands. Coppice poles and thinnings from the broad-leaved plantations are utilized by the wood-turners in and near the forest, and oak bark is again finding a market. All timber, poles, and coppice are cut by woodmen employed by the Forestry Commission at piecework rates and extracted over approved routes by the purchasers or by contractors. The upkeep of forest roads is a considerable item, and as might be expected in a highly mineralized area the forest is well served by railways.

ADMINISTRATION.

The Forest of Dean has, since its transfer to the Forestry Commission, been incorporated with what is now Division No. 7 (England and Wales), of which it is the most important unit. The Division is locally in charge of the Deputy Surveyor of the forest, who is also Steward of the Crown Manors and an Inspector of Railways within the forest. For the work in the forest the Deputy Surveyor has the part-time assistance of the Instructor (District Officer), in

charge of the Training School for Foresters at Parkend, and of a Head Forester, and the forest is, for administrative and management purposes, split into five beats, each under a resident forester. The Deputy Surveyor's residence and office remains at Whitemead Park which has been the local administrative centre for over two hundred years, and which is conveniently situated close to Parkend.

The mines and minerals are managed, on behalf of the Forestry Commission, by the Deputy-Gaveller whose office is one of very ancient origin.

The Highmeadow Estate of 3,580 acres, which lies to the west of the forest, is excluded from the scope of this article. These woods form a separate administrative unit and have at no period of their modern history formed part of the Forest of Dean. The woods extend to 3,349 acres and were acquired by the Crown by purchase during the period 1817 to 1828 under the authority of 57 Geo. III, c. 97.

CORSICAN PINE IN GREAT BRITAIN

BY H. M. STEVEN

INTRODUCTION.

CORSICAN pine (*Pinus nigra* Arnold var. *calabrica* Schneid.) was introduced into Great Britain more than 150 years ago. The exact date is uncertain owing to confusion in nomenclature, but it is generally considered to be 1759. Its possibilities as a forest tree in this country have been realized for a century, and single or groups of trees approaching that age are to be found in different parts of the country, but there are few plantations more than about 60 years old. The oldest known and most notable was at Highclere, Berkshire, which dated from about 1837. Although prior to the War there was a number of Corsican pine plantations in different parts of the country, and particularly in the south of England, their extent was, in most instances, small, and no large tracts of the species were known. Since the War Corsican pine has been used on a much larger scale, particularly by the Forestry Commission, and it may be opportune to review what is known regarding it.

HABITATS.

P. nigra, other than var. *austriaca* Asch. and Graebn., is a Mediterranean species, occurring naturally at a number of stations round that sea, and on its islands. In the west, it forms large forests on the Serranias of Cuenca, and of Cazorla and Segura in east-central Spain (8), where it occurs at altitudes of 2,500 to 5,500 feet; and on calcareous soils derived from Jurassic and Cretaceous formations. The height attained by the trees is stated to equal that in Corsica and Calabria. It is to be found on the Pyrenees, both French and Spanish (4), at 2,000 to 4,500 feet, the lower limit being where conditions are humid. The tree in the Pyrenees, however, does not grow more than 40 to 50 feet in height. The other westerly station is on the Cévennes in south-east France. Olazabal (8) considered that the Spanish *P. nigra* constituted a separate variety, *hispanica*; but it would appear that all the above should be grouped under the Salzmann or Cévennes type, now known as var. *cebennensis* Redh.

Corsican pine forms fine forests on the Sila *massif* in Calabria, in the south-west of Italy (6). The soil is a coarse sand derived from crystalline schists and granite, and the altitude 3,000 to 6,000 feet, the average being about 4,000 feet. One striking point about the species in Calabria is the great variety in type of cones, needles, bark, and branching; there appears to be every gradation from typical Austrian Pine type var. *austriaca* Asch. and Graebn. to the type in Corsica, more or less side by side. A height of over 100 feet is attained.

Corsican pine (inclusive) occurs at a number of places at the eastern end of the Mediterranean Basin—on the mountains of Greece, in Crimea, on the Taurus Mountains in the west of Asia Minor, and on the mountains of Cyprus

and Crete. It has also been reported from Algeria (11). The Crimean and west Asiatic form has been termed var. *caramanica* Rehd. There is little published information regarding the eastern occurrence of the species (11).

It is believed that most of the Corsican pine used in this country, except certain recent lots, has been raised from seed from Corsica, hence this is the most important habitat from the British point of view. The forest conditions in Corsica have been described by several observers (1), (9), and (10).

The island is built up of granite and porphyry which give a light, deep, sandy loam. Corsican pine attains its best development between 3,000 and 4,000 feet above sea-level. Below 3,000 feet it merges into *P. pinaster* Ait., or in places chestnut, which is grown for its fruit, the lowest vegetative zone being the Corsican *Maquis* consisting of *Ericas*, *Arbutus*, etc., while above 4,000 feet it is mixed with beech and birch, finally disappearing at about 5,000 feet. In its optimum zone, it forms pure high forest without any underwood. It is managed on a loose group selection system, the rotation being 360 years. The reason for the long rotation is the desire for a high proportion of heartwood which increases more rapidly after 280 years. One of the biggest trees, 'le roi des arbres', at Valdoniello is estimated by Saliceti (10) to be 1,000 years old. The species regenerates freely in gaps, but the regeneration is often destroyed by fire. A height of over 120 feet and a diameter of over 3 feet is attained under the most favourable conditions.

Data regarding the climate of the different stations are not abundant. It would appear, however, that it is typically Mediterranean (11); the rainfall is generally over 50 inches, but largely a winter rainfall, there being three or four months in summer which are very dry. Snow may occur in winter, but the summer is very hot. As the soils, whether siliceous or calcareous, are generally deep and loose, the species is subjected to severe drought conditions, particularly in early life, before its root system is fully developed.

B. U. Byles studied this and other Mediterranean species in their principal habitats and collected much valuable data. His notes, however, have not been published; they are filed in the Forestry Department, Canberra, Australia.

There have been no critical experiments made in this country with *P. nigra* varieties or geographical races, and there is room for such. The evidence available from existing plantations of different races, however, is that the race from Corsica is superior in silvicultural characteristics, particularly rate of growth and light branching, and is the best for the conditions in this country.

SILVICULTURAL CHARACTERISTICS.

Root System.

The root system of Corsican pine in early life has been described in detail by Aldrich-Blake (1). After the seed germinates, the radicle grows very rapidly, depths of 1 to 2 feet or more being attained during the first season. The radicle bears numerous lateral root initials, but few of these develop, hence a poorly branched root system results. This type of root system has no doubt arisen

through the selective action of summer drought conditions in the habitats of the tree.

The adult root system consists of a horizontal and moderately superficial part, a central vertical portion, and a scattered vertical system. The horizontal spread is not typically great, namely a radius of about 7 feet. While the tap root is prominent in early life, the scattered vertical system becomes more important with age. The root system is deep in easily permeable soils, but observations in this country indicate that it does not penetrate into chalk or other hard strata, which penetration has been observed on the Continent.

The type of root developed in early life makes the species difficult to transplant and plant, without the risk of high losses, but when established it is adapted to sites subject to drying out.

Rate of Growth.

The slow growth of the shoot during the first season contrasts with the rapid growth of the radicle. Under average nursery conditions it is 1 inch with limits of ½ inch and 2 inches. Growth during the second year is faster, namely 2 to 6 inches, and, if the seedling is undisturbed, growth in subsequent years increases rapidly. In direct sowing, growth is much slower, due to the less favourable conditions. Nursery stock, normally 1+1 or 2+1, when planted out on average sites does not begin to grow fast until the third season. The growth in the first season is typically 1 to 3 inches, a little faster in the second, and by the third 6 to 12 inches may be expected. Thereafter growth progressively increases, in the absence of inhibiting site factors. Height growth in plantations during the first few years is generally very irregular, individual trees varying widely in height.

The data in the British Yield Tables (5) show that at 10 years the mean height in Quality Class I (70 feet at 50 years) is 12 feet, and in Quality Class III (50 feet at 50 years) 7 feet. Height-growth increment is greatest between the 10th and 20th years, namely 18 feet for Quality Class I, followed by 15 feet between 20 and 30 years, 13 feet between 30 and 40 years, and 12 feet between 40 and 50 years. The height attained in 80 years in the Highclere plantation already referred to was 104 feet, hence the species is as vigorous in this country as in any of its habitats. As regards different parts of the country, growth is fastest in the south of England.

Stem and Crown Form.

The outstanding characteristic of the stem form of Corsican pine is its straightness. It is superior in this respect to all other pines grown in this country.

In *P. nigra* there are two strongly contrasted types of branching; hence crown form. On the one hand, there is a type in which the branches bend upwards and grow almost as fast as the leading shoot, so that a rounded, bushy crown is formed; and on the other, a type where the leading shoot is strongly

defined and a pyramidal crown results. The bushy crown is typical of the Austrian variety, and the pyramidal of that from Corsica; in Calabria both types occur (6). As far as is known, the other varieties tend more to the Austrian than to the Corsican type. In this country the typical Corsican pine has a markedly pyramidal crown, but there is a considerable variation in thickness of branches and density of crown under similar stocking. This is to be expected from the variations which occur in its habitats. There is scope, therefore, for improvement of type, namely towards light branching and pyramidal crown, by systematic thinning favouring the best crown forms, even when stock is raised from origins good in this respect.

Frost Hardiness.

Corsican pine has generally been considered to be frost hardy in this country; no instance of killing by winter cold is known. Unseasonable frosts, however, may do serious damage. Several instances of the killing of elongating shoots by June frosts have been observed, but no extensive damage; early frosts have been more serious. In the third week of September 1932 many Corsican pine up to 5 feet in height were damaged or killed by an early frost in Nottinghamshire and Lincolnshire. The damage was to the cambium, which resulted in the dying-back of shoots to a varying degree, and in some instances the whole tree was killed. In August of the same year, frost killed or damaged young Corsican pine near Burghead on the Morayshire coast. Corsican pine cannot, therefore, be classified as a frost-hardy species, at least during the first seven years of its life.

Resistance to Smoke Damage.

In that part of Nottinghamshire which was once Sherwood Forest, Corsican pine was planted fairly extensively before the War in small plantations and shelter belts. The vegetation type was generally heath, probably derived from degenerate Oak-Birchwood, and the soil a sand or gravel derived from Bunter Sandstone. The district has been industrialized, particularly by the development since the War of the Nottinghamshire coal-fields, and it is now a definitely smoky district, and here Corsican pine stands out as a smoke-resistant species. It has retained its normal form, and growth is still satisfactory, while Scots pine shows poor form as the result of the die-back of shoots, and growth is much under normal. Nevertheless, the size of old Scots pine shows that the conditions were suitable to this species before there was smoke pollution.

This and similar evidence from other districts indicates that Corsican pine is one of the conifers most resistant to smoke damage.

Resistance to Insect Pests.

Corsican pine, in contrast with Scots pine, is a healthy species. Most of the common pine insect pests attack it, but to a much less degree. Its resistance is probably due principally to the higher resin content of its tissues.

Pine Tortrix. Rhyacionia buoliana Schiff does damage to Scots pine during

the first 15 years in some parts of this country, for example in east Anglia. Even where this pest is very abundant, however, it very rarely damages Corsican pine, although this species is attacked.

Pine Sawflies. Lophyrus spp. attack Corsican pine, but they are rarely numerous on it, and no instance of complete defoliation has been seen.

Pine Lachnus. In 1931 and 1932 this aphid was abundant on young Scots pine in different parts of the country, and caused defoliation of 1-year and older needles, and checking of growth. Even when mixed with heavily infected Scots pine, the Corsican pine was practically unattacked.

The Pine Shoot Beetle and Pine Weevil both attack Corsican pine, although not generally so severely as Scots pine. Both these pests, however, are amenable to control. The so-called Heather Beetles (*Strophosomus lateralis* and *Otiorrhynchus* spp.) have on occasion done damage through destruction of needles to newly planted Corsican pine in Nottinghamshire and elsewhere, but they are not generally serious pests.

Resistance to Fungal Diseases.

The only fungal disease which has threatened to be serious to Corsican pine is *Brunchorstia destruens* Erikss. (10). Austrian pine is more susceptible, but in areas of high rainfall and at the higher altitudes, particularly in north Wales and the Isle of Man, serious damage has been done to Corsican pine by this disease, plantations being wiped out. It is probable, however, that Corsican pine is unsuited to a cold, wet climate, and this reduced its resistance in such instances.

Resistance of Rabbit Damage.

At one time it was believed that rabbits would not eat Corsican pine plants. This is not so, but rabbits prefer other species, and in mixtures Corsican pine is generally left where rabbits have access.

NURSERY PRACTICE.

There are on the average 35,000 seeds per pound, and the laboratory germination test by Jacobsen or Hearson methods should be 70 to 90 per cent., although lower-quality seed is common. Under average nursery practice, 10,000 1-year or 2-year seedlings are produced per pound of seed, but higher yields up to 20,000 are possible.

Manuring. A humus-rich sand is the best soil for the raising of Corsican pine. The lighter the soil, the less damage is done at the time of lifting, and this is especially important in this poorly rooted species; while large quantities of humus improve the type of root from a handling point of view, although it depresses the root/shoot ratio. It is considered important to maintain a high phosphoric acid content of the soil for this and all coniferous species. The best results are obtained with heavy dressings of hardwood humus or well-rotted farmyard manure applied to seed-beds, with 4 cwt. of basic slag applied with a green crop in rotation every third or fourth year. Where humus

manures are not available, the next best treatment is steamed bone flour at the rate of 5 cwt. per acre.

Method and Density of Sowing. Corsican pine being a deep-rooted species does not respond to drill sowing in the same way as a shallow-rooted species; broadcast sowing generally gives satisfactory results (12).

Thin sowing gives larger production and larger plants, and a density of 350 square feet to the pound is recommended.

Season of Sowing, &c. The seedling is frost hardy, and where conditions of soil permit, early sowing—end of March to middle of April—is beneficial. The seed germinates readily and evenly, and the only treatment necessary is soaking in water for 24 hours before sowing.

Shelter. The seedling is not sensitive to sun scorch, hence summer-shelter is not necessary. It is probably disadvantageous because it decreases the carbohydrate/nitrogen ratio in the plant which in turn tends to depress the root/shoot ratio.

Browning and defoliation as the result of winter frosts are not uncommon, and the September frost already noted damaged transplants in Laughton Nursery, Lincolnshire. Defoliation, followed by die-back of the shoot, and in some instances death of the plant, resulted. In general, however, winter protection is not necessary.

Transplanting. In the past heavy losses have been incurred in transplant lines. When the seedling is lifted the absorbing tissues are largely lost, because the root system is so extensive and poorly branched, and root regeneration is slow. If, after lining out, climatic conditions favour rapid transpiration, for example dry, windy weather, then this plant which is the product of the selective action of drought conditions, paradoxically dies of drought. Experiments carried out in the south of England (12), and practice based on these experiments, have demonstrated that 1-year seedlings suffer lower losses than 2-year seedlings, and both are best lined out during winter, namely December to February. In Scotland, the effect of season is less marked, probably because the soils dry out more slowly in the spring. Experience in several seasons unfavourable as regards spring drought has shown that abnormal losses can be avoided by improvement in seedlings by manuring, care in lifting, and winter lining out.

CONDITIONS FOR WHICH CORSICAN PINE IS SUITABLE.

The brief notes on conditions in the habitats of the species, and the discussion of its silvicultural characteristics in this country, have indicated the types of site for which Corsican pine is suited. They may be summarized as follows:

1. Climatically, Corsican pine is a Mediterranean species, and while it is everywhere a tree of the mountains and not the littoral, the summer temperatures are high, and the summer rainfall low. It does not necessarily follow that it is suited only for places with dry, hot, summers, because a species may be more adaptable than its present habitats indicate; but its behaviour in

certain humid valleys in the Pyrenees (11), and the incidence of *Brunchorstia* in this country, indicate that it should not be used under cold, wet, conditions.

Serious damage has been done by early frosts, hence sites liable to such should be avoided. The 1932 September frost in Nottinghamshire closely followed the contours, the damage being in the valleys. Where bracken occurs in a district, its absence in valleys or frost damage to it often indicates this frost-line.

These considerations indicate that the important sites for Corsican pine in this country are in the south and east of England, and the coastal fringe of eastern Scotland.

2. The adult root system makes Corsican pine very suitable for loose, deep, and light soils, liable to dry out in summer. In Corsica, the species is not considered suitable for calcareous soils, but as already noted certain geographical races occur on such soils; this and local evidence indicates that the species is suitable for the sands over chalk in Norfolk and Suffolk, and the crag soils of south-east Suffolk. It has also proved suitable for the Bunter Sandstone soils and gravels in Nottinghamshire which dry out in summer. Perhaps the most suitable soil type is the wind-blown sands and marine dunes. Examples of such suitability may be seen at Holkham in Norfolk, Merthyrmawr in south Wales, Tentsmuir at the mouth of the Tay, and Culbin on the Morayshire coast.

On leached and compacted soils with thin, heath, peat, Corsican pine checks more severely than Scots pine. Such limited experience as is available of cultivation on such soils, however, indicates that this can be eliminated in this way, and it would appear that this species is well adapted for such soils in the south and east of England which would be improved by a deep-rooting species that would tap the lower and richer soil horizons.

3. The resistance to smoke makes Corsican pine suitable for sites subject to pollution in this way where the climate and soils permit.

4. Where the growth and form of Scots pine is seriously affected by insect pests, for example Pine Shoot Moth in Norfolk and Suffolk, there is much to be said for the substitution of Corsican pine on this ground alone.

5. The superior straightness of stem makes Corsican pine more suitable than Scots pine for exposed places where the choice lies between these species, and the conditions are otherwise suitable for Corsican pine. There is thus a place for it on such sites and particularly on the lower hills in the south-west of England.

The major pine areas, existing or potential, in England are in the south and east, and on purely silvicultural grounds Corsican pine could be usefully substituted for Scots pine on a large proportion of these sites. How large it should be depends on other considerations, particularly quality of the timber. It is not considered that there is a large place for Corsican pine in Wales, except on littoral dunes. In Scotland, similarly, the suitable sites are largely coastal. In the interior of the country, and particularly in the great pine areas on the valleys of the Dee and Spey, the climatic conditions are unsuitable,

and while evidence is very limited, such as there is indicates that Corsican pine is not so vigorous as it is in districts with hotter summers.

ESTABLISHMENT.

Direct Sowing. The type of root system of Corsican pine indicates that direct sowing should be the best method of forming a crop artificially. During the past 15 years extensive experiments have been made in different parts of the country with direct sowing of Corsican pine seed, but the successes were very few. The principal reasons for failure were destruction of seed by birds, and of seedlings by insect pests, particularly chafers. Moreover, the slow shoot growth in early life, except where seed-bed conditions are very favourable, makes the method difficult, because Corsican pine plants are very light-demanding in this country, and intolerant of smothering by weeds. From experience of direct sowing of this and other species in this country, it has been found that the method is unreliable and unsatisfactory, except where the site has been forest very recently, and the conditions of soil and environment still remain forestal.

Planting. The same difficulties are experienced in planting as in transplanting in the nursery, and for the same reasons. High losses have been sustained, but improvements in technique have made results much more certain. On sites not likely to become weedy in the years immediately following planting, for example on sand-dunes and on ploughed and relatively infertile sands, 1-year 1-year transplants give the best results, while on weedy and in particular grassy sites, 2-year 1-year or 1-year 1-year 1-year are necessary. Experiments have been made with 1-year and 2-year seedlings; high losses were experienced with 1-year, while 2-year generally gave less certain results compared with transplants. The plants are sensitive to aeration and check when it is poor. Where there is a skin of peat or a close mat of vegetation, for example *Polytrichum juniperinum*, it is preferable to plant in a ploughed furrow, or in a screef with loosened soil. A deep vertical notch, for example with a Schlich spade, with adequate firming, is the best method of planting. Experience has shown that winter planting, namely from December to February, gives good results more consistently than later planting, particularly in the south and east of England. Corsican pine is usually planted in this country at an espacement of 4 feet 6 inches or 5 feet. The principal considerations in determining the espacement of a species in artificial formation are:

(*a*) economic—the widest espacement which will meet silvicultural requirements;
(*b*) the closing of the plantation, and the dying of branches when the diameter of the bole is small, so that the core of wide-ringed and knotty timber will be at a minimum;
(*c*) the provision of a sufficient number of trees of good stem and crown form from which to select main crop trees on thinnings.

Corsican pine being a strong light-demanding species, and of good stem

form, can be spaced relatively widely on these considerations, and it would appear that espacements wider than 5 feet would give satisfactory results.

Weeding. It has already been stated that Corsican pine is intolerant of smothering by weeds, particularly grasses, and the plants must be kept free from herbage until they overtop it. It has been found that on grassy sites, early weeding—April and May—is desirable, repeated if necessary later in the season.

Beating up. Losses generally take place in the summer following planting, except where conditions of aeration are poor or in grass when losses may be deferred. Further, height normally increases rapidly after the second season. First beating up should not be unduly delayed, therefore, but be carried out in the winter following planting.

TENDING.

Experience in the tending of Corsican pine plantations in this country is limited, and as far as is known little is available from the natural habitats of the species.

Observations indicate that the species is strongly light-demanding, and if first thinnings are delayed, there is a tendency for the crowns to become top-heavy after opening out, followed by the bending of the stem. It would appear that the first thinning should be made when the trees are about 20 feet high, on the basis of current espacements. About 200 trees per acre from those with the best stem and crown form should be selected and marked with white paint. The periodic thinnings should be directed to favour these. The first thinning should probably be a B Grade, followed by C Grade thinnings. Heavy thinning will probably prove necessary in order to secure a sufficiently rapid decay of the fall of needles, because they are resistant to decay in the dry conditions where the species is used normally.

There is not sufficient evidence available on which to form a final conclusion on the advisability of pruning, but if it proves economic at all it will be for the selected and marked trees, and it will probably prove advisable to prune at least up to 12 feet as soon as the branches die, that is, early pruning is advocated if it is done at all.

PRODUCTION.

Twenty-eight sample plots were measured by the Forestry Commission, and the data for each, and yield tables based on them, were presented in Bulletin No. 10. All but six were in Quality Class I (70 feet in 50 years). Of these six, three were in Quality Class II (60 feet in 50 years), and three in Quality Class III (50 feet in 50 years), and the latter were all in Scotland. The available evidence indicates that Quality Class I can be expected except on exposed sites. For that Quality Class, the final crop yield table volume at 50 years is 5,050 cubic feet, quarter girth, which compares with 3,530 cubic feet for Scots pine Quality Class I (60 feet in 50 years), while the volumes of the mean trees are $17\frac{1}{3}$ cubic feet and $9\frac{1}{2}$ cubic feet, respectively. The volume of the Highclere plot already referred to was 9,900 cubic feet at 80 years. From measurements

made in contiguous stands of Scots and Corsican pines in different parts of the country, it was found that Quality Class I (70 feet) of Corsican pine was associated with Quality Class I (60 feet) of Scots pine and so on, except in Scotland. A plot at Ballogie, Deeside, indicated that under such conditions the growth of Corsican pine did not exceed that of Scots pine. Under coastal conditions in Scotland, however, it shows the same superior growth compared with Scots pine as in England. There is no doubt, therefore, that in conditions for which it is suitable Corsican pine will produce much larger volumes per acre—on the average 40 per cent.—compared with Scots pine, and will also give a much larger tree in a given time.

THE PLACE OF CORSICAN PINE IN BRITISH AFFORESTATION.

Hiley (7) calculated the financial return from Scots and Corsican pines on the basis of the yield-table data already quoted. He found that the money yield from the two species would be the same if the timber of Corsican pine fetched about 60 per cent. that of Scots pine.

The discussion in previous sections has indicated the place which Corsican pine should occupy on silvicultural grounds; the crux of the question is the quality of the timber. The Forest Products Research Laboratory has carried out tests on this wood (2) and (3), both as pitwood and as timber. These showed that while Corsican pine was a little weaker than Scots pine as pitwood, it could be considered equal in value as such. The timber was suitable for general joinery work, box-making, and sleepers. These tests, however, were based on limited data, and it is hoped that further evidence on this species will be available in due course.

In the meanwhile, there are good reasons for using Corsican pine in preference to Scots pine on all sites where it has shown itself to be definitely more suitable, namely, on marine sand-dunes and east coastal conditions generally, and in smoky areas where the soil and climatic conditions meet its requirements. Its use in preference to Scots pine is also justified on part of those sites where Scots pine does well, but Corsican pine does better, namely on the deeper loose sands and gravels of the eastern counties and the south of England, particularly where Scots pine is deformed by such insect pests as the Pine Shoot Moth. The total displacement of Scots pine by Corsican pine may be justified later on such sites, if it can be shown conclusively that its timber approximates closely in quality and value to Scots pine, but to do so on present evidence would be taking undue risks.

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THE SOILS OF THE TEINDLAND STATE FOREST

A Preliminary Survey

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I. AIM OF INVESTIGATION.

FOR a number of years afforestation has been carried out on the Teindland Forest, but no data on the nature and composition of the soils have been obtained. It was, therefore, considered desirable to make a survey of the soils and to collect typical specimens for laboratory investigation.

Since the soils examined all fall into the great group of podzol soils, it is advisable to preface the account of the investigation with a brief description of the main morphological features of podzol soils and the processes giving rise to these features.

II. GENERAL ASPECTS OF PODZOLIZATION.

Podzol soils owe their name to the presence of an ashy-grey layer which underlies the surface layer of dead vegetation and plant roots, 'zola' in Russian meaning ashes. The presence of this grey layer in woodland and heath soils had long been known, but it was not until the beginning of the present century that a correct explanation of its formation was given.

The general appearance of a strongly podzolized soil is as follows, the horizons being given the conventional letters which are explained later.

(1) A_0. Consists largely of decaying organic remains.
(2) A_1. An intimate mixture of completely decayed organic residues and mineral matter, dark grey in colour.
(3) A_2. Ashy-grey to whitish in colour, low humus and clay content.
(4) B. Sharply differentiated from A_2 in colour and texture; is rusty or yellowish brown in colour but may be almost black; contains more clay than A_2; is usually more compact and may be indurated. This layer is usually subdivided into B_1, B_2, &c.
(5) C. Parent material.

A straightforward ultimate analysis of the various layers of a podzol soil shows that in the grey layer silica largely preponderates over the other constituents, these, for example the sesquioxides, being rather low. On the other hand, when the layers underlying the grey layer are considered, an immediate increase in the amounts of sesquioxides is observed, while the percentage of silica is correspondingly lower. As a rule the clay content of these lower layers is also higher. These facts suggest that there has been at work in the soil a leaching process, carrying down sesquioxides, bases, and clay, while the silica is left behind.

On examination of the climatic data for the regions in which podzols occur—the cool temperate region—it is observed that atmospheric precipitation always exceeds evaporation. Thus, the cause of the leaching of the soil constituents from the upper to the lower layers is at once apparent. The rain soaking into the soil dissolves or carries down the various constituents in the colloidal state. Bases, for example lime, magnesia, &c., will be carried down in true solution or as adsorption compounds with the colloids, while the sesquioxides will be removed in the colloidal state. Some of the iron, of course, may be leached as the ferrous ion.

These constituents are not leached entirely out of the soil, the sesquioxides and some part of the bases being deposited at quite a short distance from the grey layer, imparting a rusty tinge to the soil. The boundary between these two layers is usually very sharp. On account of this deposition of sesquioxides, &c., this layer is known as the illuvial horizon (designated B), the leached layer above being known as the eluvial horizon (designated A_2).

The above description gives in a general way the chief features of a podzol soil and the method of its formation. A more detailed explanation of the processes at work in the leached layer has been given by Gedroiz (10) as a result of his experiments on the soil-adsorbing complex. This may be summarized as follows. Under the climatic conditions prevailing in the podzol zone, there is a constant leaching of bases from the upper, or eluvial, layers of the soil, and since under coniferous forest and heath the organic remains are very poor in bases, hydrogen becomes the predominant cation in the adsorption complex. Gedroiz found that a soil-adsorbing complex when saturated with hydrogen became very unstable in contact with water, and tended to break up into its main component parts, for example silica and the sesquioxides. These are set free in the colloidal state, and since the sesquioxides are readily peptized by humic substances, they are quickly removed from the seat of decomposition. Silica is only soluble to a very slight extent in acid solution, and so for the most part is left *in situ*. Data for the mineral constituents of river water show that silica is present in very small amount (6).

The precipitation of the sesquioxides in the illuvial horizon has not yet been fully explained, and numerous theories have been propounded. The first to study the problem in a quantitative manner was Aarnio (1, 2). On the basis of his experiments, he put forward the view that an increase in concentration above a certain limit brings about a flocculation of sesquioxide sols. He also found that silica and humus colloids could precipitate iron and alumina sols, especially the iron sols.

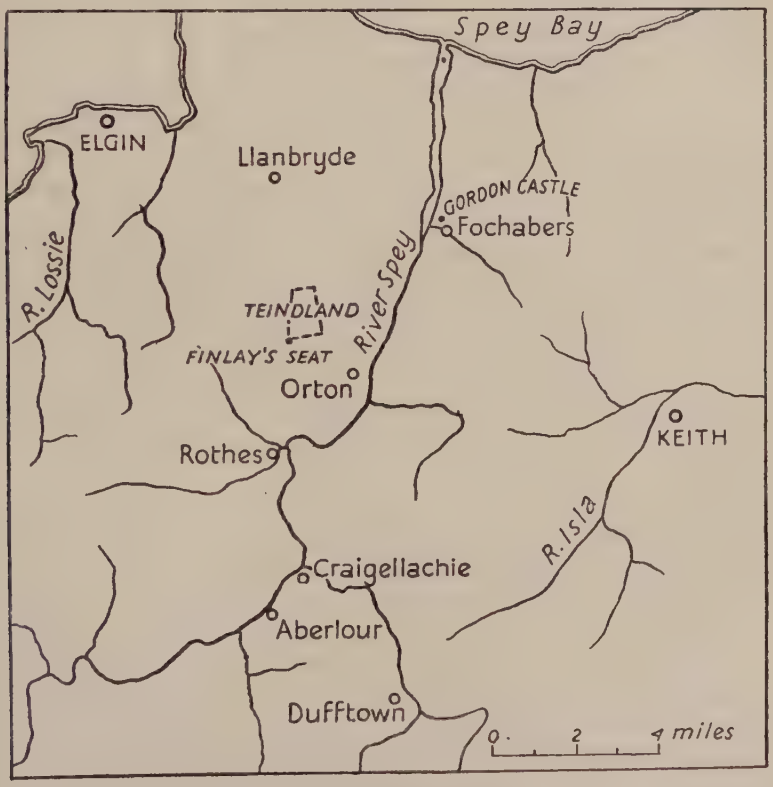
A fact of importance in this connexion has been brought out in the literature recently—that is, the pH of the illuvial layer of podzols tends to approximate to a value of 4·7 (22, 25, 26, 30). This would appear to show that the base status of the illuvial horizon also plays an essential part in the precipitation of the sesquioxides. Joffe (15), as a result of a study of American podzols in conjunction with Mattson's theories of soil colloid behaviour, comes to the conclusion that 'the electrostatic forces causing the movement of the anionic

constituents (i.e. R_2O_3, &c.) is regulated by the pH of the medium and the presence of electrolytes'.

In the above description of podzolization it has been assumed that drainage was quite normal. If, however, drainage is impeded in any way the soil acquires quite different characteristics and properties, although it may retain some of the normal podzol features. This will be the case if the impedance is of a temporary or intermittent character, and the conditions are otherwise favourable for podzolization. The features of these soils will be considered later, when the morphology of the Teindland soils is being considered.

III. THE TEINDLAND STATE FOREST.

Situation. The Teindland Forest is situated about 7 miles from Elgin on the Elgin–Orton road, and occupies the north-east portion of Finlay's Seat, a hill of some 860 feet in height (see map). The area of the forest is about two square miles.



Sketch map of Lower Strathspey.

Physical Features and Surface Geology. Finlay's Seat rises very gently from the surrounding undulating plain and has all the characteristics of a well-glaciated hill. According to Bremner (5) three great ice movements have taken

place in north-east Scotland, and it is to the last of these that the present surface form of the country is largely due. During its advance the ice sheet modified the results of former glaciations, laying down new deposits and further rounding off contours. When the ice retreated it did so by stages, and many of the minor features of the present surface are due to the melt-water flowing from and along the edge of the ice sheet.

That part of the hill occupied by the forest can be divided into three distinct geomorphological elements with which are associated very closely both soils and vegetation.

The three elements are:

(1) The upper slopes (above 700 feet) which do not seem to have suffered any fluvio-glacial action.

(2) The fluvio-glacial channel margins which are found on the northern face of the hill, and run almost parallel to the Red Burn.

(3) The overflow channels which are found up to a height of about 700 feet.

The second and third elements are of great importance for the purpose of elucidating the development of the surface form, and will yield valuable evidence on the retreat of the third ice sheet.

As far as the hill itself is concerned there seem to have been several stoppages of the ice sheet during its retreat. The first would appear to have been about the 600-foot contour when the melt-water cut out the deep channel which is now occupied by Ladies Moss. The next must have been just a little to the north of Cushley Moss, the upper part of the Red Burn being a portion of the over-flow channel cut at this stage. To the east of the burn, there is a deep channel which would appear to have been at one time part of the course of the burn. The third stoppage would appear to have been just about Altonside Farm, when the series of channel margins on the northern part of the forest would be laid down. The actual retreat of the third ice sheet must have been a more complicated process than here outlined, because there are other smaller features which must belong to this period, but which do not seem to fit into this general scheme.

The deposits on the channel margins are quite distinct from those in the overflow channels and on the upper part of the hill. The main drift in this area is a purplish red boulder till—the colour indicating its origin from the old Red Sandstone rocks which it presumably overlies. There are no exposures of solid rock in the immediate neighbourhood. This red till is of considerable depth; on Teindland itself there is an exposure of some 4 metres without any marked change being noted. Near Rothes a depth of 7 to 8 metres for the ground moraine of the third ice sheet has been recorded (5, 17), while a total depth of drift of some 60 metres has been recorded at various places in the district (17). The till is extremely stony, and many of the stones are pebbles from the Old Red Conglomerate rocks. It is not particularly compact, and certainly much less so than the boulder till in the neighbourhood of Aberdeen. Occasionally small pockets and bands of a light fawn compact silty material are found interspersed in the red till. These bands are probably due to small

streams running under the ice. This red till is found over the whole of the upper part of the hill and at the bottom of the overflow channels.

On the channel margins and on the eastern lower slopes, the drift is of a sandy gravelly nature and of a fawn to pinkish-fawn colour. There is no definite indication of banding in these deposits, but there is a great variation in these gravels. Two pits dug about 50 yards apart showed very marked differences in them. One was extremely stony, the stones being well compacted, while the other contained only a moderate amount of stones and the whole deposit was quite loose. These fluvio-glacial deposits gradually thin out with increasing height until at about 600 feet on the west side and at about 450 feet on the east side of the hill they disappear. Profile 27 shows only about 50 cm. of the sandy drift. There is a long narrow belt of river alluvium on either side of the Red Burn.

The area of peat is not large, being confined to the overflow channels. It is of no great depth, 70 cm. being recorded in Cushley Moss and about 100 cm. in part of Ladies Moss. The peat appears to consist largely of heather and deer-grass remains, but a small area of rush peat was seen in one of the channels.

Climate. Climatic data for the Teindland itself are not available, hence we have to make use of those for Gordon Castle and Lhanbryde, since these are the nearest places at which weather records are kept. Gordon Castle lies about 4 miles to the north-east, while Lhanbryde is 4 miles to the north of Teindland.

The following table gives the data for rainfall and temperature for the two periods 1881–1915 and 1924–33. Rainfall data for Lhanbryde are not available in the *Book of Normals* (4), while there are no temperature records at all. Soil temperature records for Craibstone are the only ones available for north-east Scotland, but for comparison these are given.

	Rainfall.		*Temperature.*	
Period.	*Gordon Castle, 101 ft.*	*Lhanbryde, 310 ft.*	*Air at Gordon Castle.*	*Soil at Craibstone.*[1]
1881–1915 . . .	29·77 in.	..	46·6° F.	..
1924–33 . . .	28·52 in.	31·05 in.	47·1° F.	45·9° F.

[1] For the period 1925–33. The thermometer is at 1 ft. below the surface.

The rainfall figures are both within the average for the east coast of Scotland which is about 30 inches. As is seen the difference in height between the two stations makes quite an appreciable difference to the rainfall values, and since the Teindland lies at an average height of about 600 feet the rainfall there will be still higher. From the *Book of Normals* it is seen that the first six months of the year are much drier than the second six; February and April are the driest months of the year.

The air temperature values are reduced to sea-level by the application of the conventional factor of 1° F. for each 300 feet, so that the temperature of the

Teindland will be about 2° lower than the values given in the table. July and August are the warmest months, the coldest being December and January.

Vegetation. As was mentioned in the section on the physical features of the area, the vegetation is closely connected with the three geomorphological elements into which the hill can be divided; we thus have three main vegetation areas.

(1) On the lower slopes and on the channel margins where the nature of the drift gives rise to good drainage conditions the vegetation consists mainly of *Calluna vulgaris* and a few mosses of the *Hypnum* and *Dicranum* genera, while *Erica cinerea* is often encountered.

(2) The fluvio-glacial overflow channels are usually filled with peat of no great depth. The vegetation here consists largely of *Calluna vulgaris*, *Scirpus caespitosus*, *Eriophorum vaginatum*, mosses of the *Sphagnum* group, and *Cladonia* sp. (see Plate II).

(3) On the upper slopes of the hill drainage is poor owing to the presence of a very impervious hardpan with the result that the vegetation has deteriorated. *Calluna* and *Scirpus* are found here as codominant species with a very strong growth of the lichen *Cladonia*. Pine scrub of about 70 years old is present (see Plate II (*c*)). This *Calluna-Scirpus* association has covered the whole of the upper slopes, but is now being eradicated by ploughing and the application of basic slag.

According to the Ordnance Survey map of 1887 the entire hill was covered with trees at that date, but judging by the age of the relics seen in the photographs these must just have been planted. On the lower slopes all the former trees have been cut down, but from the stumps it is seen that the sands and gravels provided the best medium for the good growth of Scots pine. Plate I (*a*) and II (*c*) show up this feature. The trees seen in I (*a*) are about 10 years old and are growing on the sands, while those in II (*c*), growing on the boulder till, are about 70 years old.

IV. MORPHOLOGY OF THE TEINDLAND SOILS.

A. *General.*

The soils all fall into the great group of podzol soils, and may be subdivided into three main types:

(1) Normal podzols on fluvio-glacial sands and gravels.

(2) Peaty gley[1] podzols with hardpan on boulder till.

(3) Peat gley soils on boulder till.

Each soil, of course, shows a certain amount of variation from the standard, but on the whole the morphology of each is so characteristic that it can be placed without any hesitation into one of these three types.

Vegetationally each type shows a marked difference from the others. *Calluna* is common to all the types, but the plants associated with it allow the

[1] Gley is a Russian term used to indicate the presence in the soil of a horizon in which the reduction of iron from $Fe^{\cdots}$ to $Fe^{\cdot\cdot}$ takes place owing to lack of aeration. The gleyed horizon is usually of a greenish or bluish colour.

soils to be determined very readily. Thus on the normal podzols mosses of the *Hypnum* and *Dicranum* genera are found in addition to the heather; *Plagiothecium undulatum* was very abundant around profile 44. These mosses are not observed on the other soil types. *Scirpus caespitosus* and mosses of the *Sphagnum* species characterize the peat gley soils, while the abundance of *Cladonia rangiferina* on the upper slopes is very characteristic.

The three soil types are closely connected with the three geomorphological elements into which the hill can be divided, although it is doubtful if the surface form by itself has played any definite part in the development of these soils, except in the case of the peat gley soils. In the case of these last, the impedance of drainage at the bottom of the overflow channels has been caused by their relative flatness, there being insufficient slope to ensure a rapid run-off of the water collecting at the bottom.

The normal podzols owe their good drainage to the nature of the underlying drift, and not to the form of the relief of the channel margins. Indeed in some cases these margins are almost closed shallow basins, and if it were not for the presence of a porous sand underneath, the soils would no doubt have acquired the characteristics of waterlogged soils.

On the upper part of the hill where the peaty gley podzols are found, it is evident that surface form alone has played very little part in the development of the soil. The slope is sufficient to provide a good run-off of surface water. The depth to which the March Ditch has been cut—10 to 15 feet in places—is a good indication of the run-off available. The boulder till is not particularly compact, and is not high in clay, so that it is to other factors that we must turn in order to find an explanation of this type of soil formation. These factors will be considered in detail when the morphology of the soils is discussed.

B. *Field Methods.*

The methods used in making the pits and sampling the soil profiles are based on the methods learned while the writer was working in Russia. A detailed description of these methods has been given by Krasiuk (16) and a short description has been issued, in English, by the Dokuchaiev Soil Institute (20). In describing the profiles a special type of form was used enabling the various features of the profile to be represented diagrammatically. These forms were based on those issued by the State Tobacco Institute to their soil expeditions, and were drawn up by Professor B. B. Polynov, the modification required for Scottish conditions being made by the writer.

C. *Description of Soil Profiles.*

1. *Normal Podzols.* Four profile descriptions of this type will be given. The pits dug were at wide intervals over the hill so that they give a good picture of the soils of the lower slopes.

PROFILE 42.

Pit dug on one of the fluvio-glacial channel margins. Height *c.* 400 feet.

Vegetation: *Calluna vulgaris* dominant; *Hypnum cupressiformae*, *H. schreberei*, *Dicranum scoparium*, planted pines. See Plate I (*a*).

A_0–A_1. 0–4(14) cm. Dark brown layer of organic remains with strong root system. In places there is a thin A_1 layer noticeable.

A_2. 4(14)–9(19) cm. Grey, fine sandy layer with slight pinkish tinge, stony, structureless. Many roots.

B. 9(19)–55 cm. Rusty brown with slight humus staining in upper centimetre or so. Black humus patches occasional throughout layer. Sandy, stony; roots common. Coarse crumb structure.

C. 55–90 cm. Pinkish fawn fluvio-glacial gravelly sand. Loose and structureless.

PROFILE 43.

Pit dug on wide shallow fluvio-glacial channel. Height *c.* 400 feet.

Vegetation: *Calluna vulgaris*, *Hypnum cupressiformae*, *H. schreberei*, *Dicranum scoparium*, young pines (planted). See Plate I (*a*).

A_0. 0–5(9) cm. Black calluna peat, containing main root mass.

A_1. 5(9)–7(9) cm. Dark grey humose sand. Coarse crumb structure.

A_2. 7(9)–14(20) cm. Light grey sandy layer with slight humus staining; suggestion of platy structure; pebbles numerous.

B_1. 14(20)–16(22) cm. Dark grey-brown sandy, with discontinuous thin iron pan underneath.

B_2. 16(22)–26 cm. Mottled dark brown and rusty brown sandy layer; many pebbles (mostly small); roots frequent, free, and friable.

B_3. 26–50 cm. Rusty fawn fine sand, free, friable, structureless, many small pebbles; roots frequent.

C. 50–120 cm. Fawn, pebbly sand, loose and free.

PROFILE 44.

Pit dug on eastern lower slopes; height *c.* 400 feet.

Vegetation: *Calluna vulgaris*, mosses, mainly *Plagiothecium undulatum*. Group planting experiment.

A_0. 0–6 cm. Surface root mat with slightly decomposed material in lower portion.

A_1. 6–7 cm. Dark grey humose sand, friable and free, stony.

A_2. 7–23 cm. Light grey, in places almost white, sand. Somewhat variable in depth. Coarse platy structure; roots numerous.

B_1. 23–45 cm. Dark grey-brown sandy stony layer, slight rusty mottling; loose; roots penetrate.

B_2. 45–55 cm. Rusty brown slightly cemented gravelly sand. Stones numerous; roots occasional.

C. 55–70 cm. Gravelly sand with occasional pockets of pure sand. Loose and free.

PROFILE 27.

Pit dug on gentle slope (angle of slope 2°); height *c.* 500 feet.

Vegetation: *Calluna*, with a few mosses, and pine scrub (35 years).

A_0. 0–4 cm. Partially decomposed organic remains bound together by calluna roots.

A_1. 4–5 cm. Greyish black layer, specks of silica. Thick root system.

A_2. 5–11 cm. Greyish white fine sandy layer with marked platy structure. Passes imperceptibly into—

B_1. 11–18(20) cm. Light olive-brown fine sand with coarse platy structure in upper portion. Humus colour becomes more intense with depth. Passes sharply into—

B_2. 18(20)–28 cm. Rusty brown fine sand with numerous small black humus spots. Structureless.

C. 28–40 cm. Yellowish fawn fine sand of fluvio-glacial origin. Varies somewhat in depth.

C′. 40–100 cm. Purplish red boulder till, fairly compact but apparently quite permeable to water.

These four profiles all show the typical features of a strongly podzolized soil. There are minor differences, but that is to be expected since, as has been stated earlier, the drifts are not perfectly uniform and in addition the position of the soils in relation to the relief is not the same in each case. There is no doubt that the relief—both mezzo-[1] and micro-relief—plays quite a large part in the development of the various horizons. It was observed in the pit for profile 43, that the leached layer was slightly thicker at the lower end of the pit than at the higher end. The actual difference in height is no more than a few centimetres.

Considering these four profiles horizon by horizon it is to be noted that the A_1 layer is not developed to any marked extent in profile 42. Where it was present it was never more than a few millimetres in thickness. According to Glinka (12) the absence of this A_1 layer is a characteristic feature of the podzols of the Northern Province of Russia. The A_2 layer follows immediately after the surface organic layer.

The A_2 layers of all four profiles are very similar in every respect except structure. The leached layer of profile 42 showed no structure whatever, even when dry, while profiles 44 and 27 showed very marked platy structure. The leached layer of profile 43 had only a suggestion of platiness. This platy structure is a common feature of podzols in general and especially of those formed from clayey or loamy deposits. In sandy soils the lack of clay prevents the cohesion of the coarser particles into structural elements.

Small iron concretions which are common in the A_2 horizons of podzols in Russia were not observed at all in any of these profiles.

The humus accumulation layer (B_1) is found in all profiles but only in one, profile 43, was there any sign of iron pan below this layer, and here it was discontinuous and very thin (2–3 mm.). The lower portion of the illuvial horizon is only cemented in one case (profile 44), and even here it is not very strong. Occasional spots and patches of humus which are found in this lower part of the illuvial horizon are common to all these profiles. In some cases this is due to the decomposition of old roots. Structure is almost entirely absent from the illuvial horizon as a whole, at the most a coarse crumb structure is all that can be observed. This lack of structure again is, no doubt, due to the sandy nature of the parent material.

Underlying these horizons is the parent material, in this case a sandy gravelly drift. This drift is of a loose friable nature and shows no structure whatsoever.

For purposes of comparison a podzol profile from the Hazlehead Policies, near Aberdeen, is given below.

[1] A term introduced by Neustruev (18) for intermediate forms of relief.

PROFILE 3.

Pit dug on flat part of ridge between two glacial overflow channels. Height *c.* 400 feet.

Vegetation: Open coniferous wood consisting of *Pinus silvestris*, *Larix decidua*, *Sorbus aucuparia*; *Pteris*, *Deschampsia flexuosa*, *Oxalis acetosella*.

Parent material: Boulder till over granite.

A_0. (1) 0–8 cm. Layer of grass and forest litter, thick root system.
(2) 8–10 cm. Coffee-brown well-decomposed organic matter, roots abundant.
(3) 10–15 cm. Black well-decomposed organic matter; may represent former calluna peat; very little mineral matter; friable.

A_2. (4) 15–18 cm. Grey with brownish tinge, silty, sandy texture, friable, and porous.

B_1. (5) 18–23 cm. Brown-grey gritty sandy loam friable and porous; slightly more compact than preceding layer.

B_2. (6) 23–46 cm. Ochrous-brown loam, gritty with many small stones, fairly compact, few black-brown spots of humus.

B_3. (7) 46–61 cm. Altered boulder till, lighter in colour than previous layer with pinkish spots of probably unaltered till. Gritty loam in texture, many stones, porous, few roots.

C. (8) 61–70 cm. Pinkish fawn boulder till, extremely compact and stony.

This area was probably covered with heather before the present vegetation was introduced and so we find that the lower part of the A_0 horizon consists of heather peat. The A_1 horizon appears to be absent. The A_2 layer is darker than that of the Teindland podzols, due no doubt to the grassy surface vegetation; it is, however, well leached, as will be seen from the chemical data to be presented. No structure is shown whatsoever. The illuvial horizon is fairly well compacted but shows no structure. It passes gradually into the unaltered boulder till.

Thus we see that on a granitic drift the soil-forming processes at work are of the same type as those which are active at Teindland. The surface mineral layer is deprived of its sesquioxides, which are deposited lower down, imparting a rusty tinge to the soil.

Podzolized soils are classified by the Russian school into sub-groups on the basis of the degree of development of the leached layer. When this layer is not developed morphologically, but can only be determined by chemical analysis or by deduction from the position of the soil in relation to climate, vegetation, &c., then the soil is said to be a concealed podzol. As leaching proceeds morphological evidence of podzolization becomes apparent in the form of small bleached spots and narrow bands. This type of soil is known as a slightly podzolized soil.

The rate at which podzolization takes place cannot be determined accurately, but two examples may be given to show that the development of the leached layer may take place fairly rapidly. Tamm (26) describes a podzol formed within the last 100 years on the shores of Lake Ragunda in Sweden. Here the grey A_2 layer has attained a thickness of about 2 cm. The writer was shown a soil at Drumtochty, Kincardineshire, which had formerly carried a forest nursery. The ground had been allowed to become overgrown with Scots pine some 20 years ago, and at the present moment a very marked leached layer of about

0·5 cm. is already visible. Since the soil was periodically cultivated while used for nursery work, the processes of podzolization would never have a chance to produce any such layer.

When leaching has proceeded to such an extent that a definite grey or whitish layer has been formed, the soils are known as medium or strongly podzolized soils. The term 'podzol' is applied to soils 'in which the whitish horizon begins near the surface and attains a considerable thickness, whereas the humus horizon A_1 is hardly developed' (18 *b*). On the basis of these definitions it can be said that the soils described above all belong to the group of strongly podzolized soils.

In Scandinavian countries the above classification does not appear to be used. Under the scheme in use there, these soils would all be grouped as iron podzols (9, 3).

2. *Peaty Gley Podzols with Hardpan.* As has been mentioned in the introduction to this section, the peaty gley podzols are found exclusively on the upper slopes where the red till comes to the surface. The main characteristic of these soils is the presence of an extremely hard and almost continuous iron pan. The formation of this pan has led to an impedance in the drainage of the layers above it, with the result that the eluvial layer is no longer of the customary grey tint but tends more to an olive-grey tone, and the ground has been invaded by a very inferior type of vegetation. As can be seen from the photographs tree-growth is extremely poor. Three profiles will be described.

Profile 41.

Pit dug on upper slopes of hill; height *c.* 700 feet. Old peat hags are very common on this part.

Vegetation: *Calluna vulgaris*, *Erica tetralix*, *Scirpus caespitosus*, mosses, and *Cladonia* spp.; poor pine scrub.

A_0. 0–3 cm. Mat of heather and other plant roots.

A_1. 3–13 cm. Black spongy peat, full of roots, with old tree roots occasional. Passes sharply into—

A_2–G. 13–45 cm. Olive-grey silty fine sand, some rusty mottling; structureless, stony, roots penetrate.

B_1. 45–6 cm. Hardpan of varying thickness. Appears to be quite impervious, and water seeped into the pit from above the pan. The layers underneath were almost dry.

B_2. 46–56 cm. Boulder till with some rusty streaking and mottling. Occasional dead roots. Stony and compact.

C. 56–70 cm. Purplish red till; patches of a brighter red, stiffer clay.

Profile 23.

Pit dug on gentle slope near top of hill. Height *c.* 800 feet.

Vegetation: Mainly *Calluna* and *Scirpus*, with very poor pine scrub.

A_0. 0–5 cm. Mat of calluna and scirpus roots.

5–11 cm. Well-decomposed peat, with many live roots; spongy when wet, but cracks on drying.

A'_2–G. 11–17 cm. Grey sandy layer, structureless; contains many stones which are somewhat bleached. Roots penetrate.

A''_2–G. 17–27 cm. Dirty olive-brown, silty fine sand in texture; structureless; many stones; slight signs of gleying.

B_1. 27–27·5 cm. Iron pan, not quite continuous but extremely hard.

B_2. 27·5–40 cm. Purplish red with slight iron staining, especially along old root channels; very compact.

C. 40–90 cm. Purplish red boulder till, looser than previous layer.

Profile 40.

Pit dug on hummock on upper slopes at a height of about 700 feet. This part very hummocky.

Vegetation: *Calluna*, *Scirpus*, *Erica tetralix*, *Carex* spp., *Cladonia* spp., *Sphagnum compactum* in wet hollows. Stunted pine scrub. Plate II (*c*).

A_0. 0–7(10) cm. Surface root mat over black well-decomposed peat. Stones occasional.

A_2–G. 7(10)–17 cm. Dark grey, sandy; humus staining throughout. Stony and free; many roots.

B_1. 17–23 cm. Brownish black humus accumulation layer, sandy and stony, roots numerous. Underlain by discontinuous hardpan which is quite thin.

B_2. 23–38 cm. Iron-stained sandy, stony, roots occasional, structureless, slightly compacted yet appears free. Slight humus staining.

B_3. 38–53 cm. Lighter in colour than previous layer, no humus staining visible. Fairly compact, stony, and structureless.

C. 53–80 cm. Purplish red till, stony, structureless; slightly compacted.

The term humus podzol has been applied to soils of this type by Tamm (27), who in this paper describes a soil very similar to the above except that the hardpan is of much greater thickness. It has, however, been decided to use the more descriptive Russian term 'peaty gley podzol' in this paper.

The formation of peaty gley podzols is due to periodical swamping, with the result that instead of the usual dry surface layer of 'raw humus', there is formed a layer of peat of some thickness. The swamping may be a result of one or other of two causes: (1) the ground-water level rises fairly high during the wet seasons, waterlogging the surface layers and giving rise to conditions of bad aeration which leads to peat formation; (2) the presence of a layer in the soil which is impermeable to water. The rain-water in this case cannot pass through the soil, but lies on the surface until it evaporates or flows away, if there is sufficient slope to permit this. In either case there is a general diffusion of humus through the upper layers. The soils here considered belong to the second class—the hardpan being the impervious layer.

Two explanations of the development of this type of soil may be put forward.

(*a*) It may be assumed that the soil developed first as a normal podzol with the formation of hardpan underlying the layer of humus accumulation. That this is possible is seen from profile 43 which has this feature. As the hardpan increased in thickness so did its impermeability to water increase until, in the end, no water could pass through. This is the case in profile 41. Thus surface waterlogging was made possible and peat formation set in. The presence of a slight platy structure in one profile examined would seem to lend weight

to this argument. If the second explanation is assumed, then this platy structure would not be present. The A_2 horizon of humus podzols is normally quite structureless.

(*b*) Due to the compact layer of heather remains which have a high absorption capacity for water, the surface layers of the mineral soils would be kept in a wet condition for fairly long periods. Under these conditions iron compounds would be reduced to the ferrous state, and as such leached out into the lower layers. These would be in a drier state and the iron would then be reoxidized and precipitated, eventually forming the hardpan.

That the boulder till is sufficiently porous to carry off any excess water was shown by the following. One of the pits had become well filled with water after heavy rain, yet it only required two or three days for the water to soak away. There is no evidence at all of a high ground-water level on the upper slopes.

That the iron forming the pan comes from the upper layers is not in doubt. The layers above it are most obviously leached, and the fact that the pan consists of a series of thin bands is certain evidence, because if the iron were brought from below there would be no chance of sufficient evaporation to enable the sesquioxide gels to pass into the irreversible form. The chemical analyses to be given in the next section also point to the eluvial horizon as the origin of the iron. The manner of its removal in the early stages of the development of the soil cannot be proved, but at the present time it would appear to be carried down in the ferrous state since the conditions of poor aeration would tend to this. The greenish tint is a good indication of the state of the iron.

The surface organic horizon of these humus podzols takes the form of a layer of peat of no great depth. The A_1 horizon which is found in some of the normal podzols is entirely absent, the peat lying directly on the bleached mineral layer. The leached layer has lost its usual colour and has acquired a greenish tint, i.e. it is gleyed to some extent. This colour is common to many Scottish moor soils especially when a layer of hardpan is present.

The waterlogging which these soils undergo has also the effect of preventing a proper expression of the humus accumulation layer which is usually found under the horizon of eluviation. In these Teindland soils, however, it is very often possible to differentiate two fairly well-defined layers above the hardpan, the lower being usually distinctly darker in colour than the upper layer. An example of this feature is seen in profile 23. Whether the darker colour is due to the deposition of dark-coloured humus substances alone, or partly to less leaching having taken place it is impossible to state without laboratory investigation. The ignition of samples from each of the layers shows at once that both are strongly leached, the humus alone accounting for the more intense colour of the lower layer.

Similar results have been recorded by Pronevich (21) in his study of the eluvial horizons of a number of Russian podzols.

The hardpan in these soils is remarkable for its continuity and its compactness.

In thickness it is fairly variable, ranging from 0·5 cm. to 10 cm. in places, but whatever its thickness it seems to be quite impermeable to water as has been noted in connexion with profile 41. It invariably has a thin matting of fine roots on its upper surface, and in none of the profiles in which it was continuous were any live roots found below it. The pan consists of a series of thin bands (1–2 mm.) strongly cementing together grains of sand and small stones. It fluctuates remarkably in depth from the surface, variations of 15–20 cm. over a distance of 1 metre being quite common. The cause of these fluctuations is not quite clear yet, but they are probably connected in some way with slight textural differences in the boulder till.

Below the hardpan there lies a layer about 10 cm. in thickness which is stained somewhat by limonite. In this layer old root channels are very common, showing that at one time it was possible for the vegetation to draw supplies of nutrients from the lower illuvial horizon. There is no sign of gleying below the pan in any of these profiles, and indeed the lower layers were usually fairly dry, indicating that the ground-water table must lie at some distance.

At the bottom of each of the profiles we have the purplish red boulder till. It is loamy to silty sand in texture and shows no structure whatsoever. It is not very compact and allows water to percolate through very readily.

3. *Peat Gley Soils.* The example of this type was taken on the Cushley Moss. The Moss lies in a slight hollow between the 600 and 700 feet contours and is connected with Ladies Moss by two narrow but fairly deep channels. Ladies Moss itself lies mainly in an outflow channel. Cushley Moss is drained by the Cushley Burn.

Profile 25.

Pit dug about 50 yards from the Cushley Burn and about the middle of the Moss. Height *c.* 600 feet.

Vegetation: *Calluna*, *Eriophorum*, *Scirpus*, *Sphagnum* mosses, *Cladonia* spp., pine scrub and planted spruce. See Plate II (*d*).

1. 0–5 cm. Matting of mosses, heather, and other plant roots.
2. 5–70 cm. Black peat, full of roots; sodden.
3. 70–120 cm. Bluish grey sandy compact layer; very stony, structureless; sodden; many decayed roots.
4. 120–50 cm. Mottled blue-grey and purplish red boulder till, sandy and very stony, but extremely compacted.
5. 150 cm. Purplish red boulder till.

The profile appears to be typical for the various mosses found in the forest as far as can be judged from exposures in ditches. The actual depth of peat is variable, but the features of the gleyed horizon are common to all the peat mosses. The blue-grey colour of the mineral horizons is due to the reduction of iron compounds to the ferrous state under conditions of permanent water-logging. That the waterlogging is actually permanent is seen from the fact that no signs of reoxidation along root channels or pores are visible. The gleyed horizon and patches are more sandy than the unaltered till. It might

be expected that with water continually flowing through the moss, a certain amount of mechanical leaching might take place.

V. CHEMICAL AND TEXTURAL PROPERTIES OF THE SOILS.

Under this heading it is proposed to consider the mechanical and chemical composition of the soils investigated. Since the soils of each type show such similarity, it is not considered necessary to submit detailed analyses for every soil. The analyses given bring out the main features of the soil types, and enable us to confirm the deductions made in the section on the morphology of the soils.

It is convenient to consider the soils in three groups as before. The methods used in the laboratory investigations were as follows:

Ultimate analyses were carried out by the standard methods as detailed in Hillebrand and Lundell (14) and Gedroiz (11). Iron was determined by the iodometric method described by Gedroiz (11). Mechanical analyses were made by the method proposed in Technical Communication No. 26, except that 20 grammes of soil were used. Exchangeable bases were determined by the ammonium acetate extraction method (24). Determinations of pH were made by the standard quinhydrone method. The separation and analysis of the clay fractions were done as recommended by Robinson (22). Iron again was determined iodometrically.

1. Normal Podzols.

Mechanical Composition.

The mechanical analyses of this type bring out very clearly the removal of the clay complex from the upper, and its deposition in the lower layers. It does not, however, indicate any chemical changes which may have taken place.

In profile 42 it is seen that there is a very marked accumulation of sand in the A_2 layer, while the clay content is extremely low. The latter rises sharply

Table I. *Mechanical Analysis of Profile 42.*

As a percentage of air-dry fine earth (< 2 mm.).

Horizon. / *Fraction.*	A_2 4–9 cm.	B_1 9–19 cm.	B_2 20–30 cm.	B_3 45–55 cm.	C 55–65 cm.
Coarse sand	53·85	41·30	39·96	50·38	53·13
Fine sand	33·20	26·60	24·67	26·10	34·90
Silt	8·45	5·97	11·77	5·15	3·07
Clay	4·80	13·53	10·13	4·70	3·68
Loss by soln.	0·15	1·78	1·59	1·15	0·58
Moisture	0·66	4·34	4·14	4·34	1·57

in the succeeding layers while the sand content falls off. With further increase in depth the sand content rises again while the clay content decreases. This feature is also shown by profile 43, but here this soil appears to be to some

extent abnormal, the B_3 horizon having a much higher fine sand content than would be expected. This feature is no doubt due to a certain amount of coarse banding in the sands although the bands are not visible.

TABLE II. *Mechanical Analysis of Profile 43.*

As a percentage of air-dry fine earth (< 2 mm.).

Horizon. / *Fraction.*	A_2 7–14 cm.	B_1 14–16 cm.	B_2 16–26 cm.	B_3 30–40 cm.	C 60–70 cm.
Coarse sand	30·08	22·46	26·12	19·94	54·83
Fine sand	53·76	42·38	43·56	54·45	33·92
Silt	10·87	9·06	9·63	9·50	4·17
Clay	4·75	12·32	10·12	9·25	4·58
Loss by soln.	0·20	1·80	1·60	1·97	1·00
Moisture	0·65	5·41	4·72	4·12	1·46

From the colour of the mechanical fractions, and from the appearance of the precipitate obtained in determining the loss by solution, strong evidence is obtained of the destruction of the adsorption complex. The fractions from the leached layer are in every case almost white, and the precipitate appears to contain very little iron. The illuvial horizon fractions, on the other hand, are strongly coloured with iron, and the precipitate appears to consist largely of that constituent. This evidence is purely qualitative, but when we consider the chemical analysis of the clay fraction we obtain very definite quantitative evidence of the degree of destruction of the adsorption complex.

The mechanical analysis of the Hazlehead profile (No. 3) is given in Table III. The soil as a whole has a much higher clay content than any of the Teindland podzols, and it is very evident that there has not been such a loss of clay from the upper horizons. In fact the A_2 horizon contains slightly more clay than the B_1 horizon. In the B_2 horizon, however, there is a definite increase in the clay content.

TABLE III. *Mechanical Analysis of Profile 3.*

As a percentage of air-dry fine earth (< 2 mm.).

Horizon. / *Fraction.*	A 10–15 cm.	A_2 15–18 cm.	B_1 18–23 cm.	B_2 23–46 cm.	B_3 46–61 cm.	C 61–70 cm.
Coarse sand	16·02	35·33	37·89	36·81	38·82	38·38
Fine sand	28·28	20·98	25·12	26·08	26·27	26·79
Silt	15·60	16·67	12·65	13·95	17·50	13·80
Clay	9·80	11·25	10·10	11·30	14·02	16·50
Loss by soln.	1·77	0·67	1·83	2·07	1·22	1·45
Moisture	11·29	3·12	6·38	4·63	2·26	2·18

Analysis of the Clay Fraction.

In the characterization of the main soil types it has become the practice to make use of the ratio of silica to sesquioxides in the clay fraction of the soil

(22). That this ratio can render great service in the classification of the major soil groups is a well-proved fact. The statistical analysis of a large number of data carried out by Crowther (7) has shown that, for American soils at any rate, there exists a definite correlation between temperature, rainfall, and the silica/sesquioxide ratio. As an indicator of the relation movements of the silica and sesquioxides in a soil profile this ratio is very useful.

TABLE IV. *Clay Analysis of Profile 42.*

As a percentage of ignited clay.

Horizon.	A_2 *4–9 cm.*	B_1 *9–19 cm.*	B_2 *20–30 cm.*	B_3 *45–55 cm.*	C *55–65 cm.*
SiO_2	52·46	39·65	37·62	28·83	36·25
TiO_2	2·13	2·05	1·84	1·08	1·00
Al_2O_3	23·23	27·72	35·24	47·39	44·40
Fe_2O_3	7·80	27·67	21·42	18·23	11·80
SiO_2/R_2O_3	2·58	1·47	1·30	0·82	1·03
SiO_2/Al_2O_3	3·03	2·41	1·80	1·03	1·38
SiO_2/Fe_2O_3	17·90	3·80	4·66	4·20	8·17

The A_0 and A_1 horizons of the soils were rejected since they contain practically no mineral matter. Considering the percentage composition of the clay fractions, it is evident that there has been considerable leaching of both iron and alumina from the upper layer, and their deposition in the lower layers. It is of interest to note that iron appears to have been carried down, in profile 43, much farther than alumina, the reverse being usually the case. The more normal distribution is shown by the other profiles. The general decrease in the silica/sesquioxide ratio is not affected by this since the increase in iron is offset by the decrease in alumina. When this fact was noted it was resolved to calculate the silica/ferric oxide ratio as well as the silica/sesquioxide and silica/alumina ratios which are usually given alone. In this way a much better conception of the relative movements of iron and alumina is obtained.

TABLE V. *Clay Analysis of Profile 43.*

As a percentage of ignited clay.

Horizon.	A_2 *7–14 cm.*	B_1 *14–16 cm.*	B_2 *16–26 cm.*	B_3 *30–40 cm.*	C *60–70 cm.*
SiO_2	59·02	46·28	31·73	33·80	35·20
TiO_2	3·59	1·19	1·82	1·50	1·00
Al_2O_3	24·20	29·92	38·36	31·62	24·56
Fe_2O_3	4·18	14·36	20·42	21·71	18·80
SiO_2/R_2O_3	3·71	2·00	0·95	1·26	1·63
SiO_2/Al_2O_3	4·12	2·61	1·03	1·80	1·92
SiO_2/Fe_2O_3	37·50	8·56	4·13	4·14	4·98

On the whole there has been a much more rapid removal of iron than of alumina from the eluvial horizon. This is brought out well by the SiO_2/Fe_2O_3 and SiO_2/Al_2O_3 ratios. In this case of profile 43 there is a decrease from 17·9 to 3·8 for SiO_2/Fe_2O_3 while SiO_2/Al_2O_3 has only decreased from 3·03 to 2·41.

That the upper part of the eluvial horizon is more strongly leached than the lower is brought out in Table VI in which the analyses of the clay fractions from profile 44 are given.

TABLE VI. *Clay Analysis of Profile 44.*

As a percentage of ignited clay.

Horizon.	A'_2 *8–15 cm.*	A''_2 *15–23 cm.*	B_1 *23–43 cm.*	B_2 *45–55 cm.*	C *60–70 cm.*
SiO_2	50·11	46·80	25·50	24·50	27·75
TiO_2	1·83	n.d.	0·94	0·68	0·41
Al_2O_3	37·95	39·77	49·30	57·41	53·65
Fe_2O_3	5·16	8·75	18·42	13·31	12·04
SiO_2/R_2O_3	2·06	1·75	0·71	0·63	0·77
SiO_2/Al_2O_3	2·24	2·00	0·88	0·72	0·88
SiO_2/Fe_2O_3	25·80	14·20	3·68	4·87	6·19

It is seen that there is quite a sharp decrease in the SiO_2/R_2O_3 ratio in passing from the upper to the lower part of the A_2 horizon, while there is only a small decrease in the SiO_2/Al_2O_3 ratio. In the succeeding layers the SiO_2/Al_2O_3 ratio for profile 44 continues to decline, whereas the SiO_2/Fe_2O_3 rises in the B_2 horizon. The alumina, on the whole, seems to be carried down much farther than the iron.

These conclusions are in accord with the results obtained by Tamm in his investigations of Swedish forest soils (26, 27). Tamm concluded that iron was the first to be removed, while silica and alumina were only removed after podzolization had proceeded for some time.

In Table VII are given the results of the clay analysis for profile 27. As has

TABLE VII. *Clay Analysis of Profile 27.*

As a percentage of ignited clay.

Horizon.	A_2 *5–11 cm.*	B_1 *11–18 cm.*	B_2 *20–28 cm.*	B_3 *30–40 cm.*	C *40–48 cm.*	*Boulder till 90–100 cm.*
SiO_2	57·80	38·50	35·10	33·90	44·20	53·76
TiO_2	2·33	1·66	1·26	0·83	0·81	0·68
Al_2O_3	23·15	45·99	42·51	46·57	41·08	28·66
Fe_2O_3	7·47	10·80	18·95	11·63	8·46	14·16
SiO_2/R_2O_3	3·05	0·82	1·12	1·07	1·61	2·42
SiO_2/Al_2O_3	4·24	1·42	1·40	1·24	1·83	3·18
SiO_2/Fe_2O_3	20·57	6·67	4·92	7·75	13·30	11·07

already been mentioned this profile was taken quite near to the upper limit of the sand and gravel region, where it was found possible to reach the boulder till which underlies these fluvio-glacial deposits. The results for the sand contrast very strongly with those for the boulder till.

In Table VIII is given the clay analysis of profile 3. As in the other soils there is a definite leaching of iron and alumina from the A_2 horizon. This leaching does not appear to have proceeded very far, however, and the point of maximum deposition of these constituents has only reached the B_1 and B_2 horizons. In the Teindland soils it was noted that the alumina had been carried much farther down the profile.

TABLE VIII. *Clay Analysis of Profile 3.*

As a percentage of ignited clay.

Horizon.	A_2	B_1	B_2	B_3	C
SiO_2	46·60	38·43	40·28	44·83	45·76
TiO_2	2·43	3·50	1·10	1·0	1·0
Al_2O_3	32·15	44·60	28·46	30·09	31·64
Fe_2O_3	12·31	20·14	23·01	17·40	12·61
SiO_2/R_2O_3	1·98	1·13	1·58	1·85	1·87
SiO_2/Al_2O_3	2·40	1·46	2·40	2·53	2·45
SiO_2/Fe_2O_3	10·07	5·07	4·65	6·83	9·65

From the above considerations it is seen that very strong weathering takes place in the eluvial horizon of these soils with the subsequent removal of certain major constituents and their deposition in the lower layers. There can be no doubt that a certain amount of weathering must take place in the illuvial horizon, and even in the upper part of the parent material but this cannot be proved by chemical analyses.

Ultimate Analysis of Profile 43.

An incomplete ultimate analysis of profile 43 is given below to show the general distribution of the total amounts of the various constituents. For the purpose of classification it is doubtful if the use of ultimate analyses is of any special value, although much the same deductions as to the movements of the various constituents can be made from it as from the analysis of the clay fraction.

From Table IX it is evident that there is a definite removal of most of the main constituents from the top mineral horizon with their subsequent deposition at various depths from the surface.

Silica. This constituent is at its maximum in the A_2 horizon and shows a decrease in the succeeding horizons, reaching a minimum in the lowest part of the illuvial horizon. It increases again in the parent material. The decrease observed is, of course, only a relative one, being caused by the increase in the amounts of the other constituents in the illuvial horizon. The actual decrease in the amount of silica present must be considerably less.

TABLE IX. *Ultimate Analysis of Profile 43.*

As a percentage of ignited fine earth (< 2 mm.).

Horizon.	A_1 5–7 cm.	A_2 7–14 cm.	B_1 14–16 cm.	B_2 16–26 cm.	B_3 26–50 cm.	C 60–70 cm.
SiO_2	89·43	91·05	82·49	78·86	76·40	83·12
TiO_2	0·14	0·12	0·24	0·21	0·21	0·11
Al_2O_3	6·11	5·81	10·10	10·30	11·08	8·56
Fe_2O_3	0·89	0·55	2·71	3·59	3·32	2·19
CaO	0·63	0·45	0·52	0·68	0·94	0·59
MgO	0·30	0·54	0·40	0·22	0·71	0·46
Undetermined residue	2·50	1·78	3·54	6·14	7·34	4·87
Total	100·00	100·00	100·00	100·00	100·00	100·00
Loss on ignition	38·73	1·77	7·87	5·66	3·92	1·63
Moisture (105°)	12·02	0·65	5·41	4·72	4·12	1·46

Sesquioxides. In the eluvial horizon these constituents are at a minimum, as has already been shown by the analyses of the clay fractions. In the lower layers, the relative movement of the sesquioxides is not the same as judged by these two methods. The ultimate analysis indicates the B_3 horizon as the point of maximum accumulation of alumina, while according to the clay analysis this occurs in the B_2 horizon. In the case of iron there is also some divergence. The B_1 horizon is the point of maximum accumulation of iron by the clay analysis, whereas according to the ultimate analysis this occurs in the B_2 horizon.

Calcium and Magnesium. The contents of these constituents vary inversely through the profile, the calcium increasing with depth while magnesium decreases. In the B_3 horizon they both reach a maximum. The high content of magnesia in the A_2 horizon may be associated with the presence of garnets which are extremely resistant to weathering. Hendrick and Newlands (13) reported a relatively high garnet content in a drift formed from Old Red Sandstone rocks near Nairn.

Potash and soda were not determined, but it may be assumed that the bulk of the undetermined residue consists of these substances. Thus it is seen that like calcium and magnesium they are accumulated to the greatest extent in the B_3 horizon.

The fact that according to the ultimate analysis most of the main constituents are at a maximum in the lower part of the illuvial horizon is in sharp contrast to the results of the clay analyses which show that the maxima occur in the upper and middle parts of the illuvial horizon. This difference makes possible an interesting field for further investigation. Rodé (23 a) as a result of his investigations of the mechanical fractions of podzolized soils came to the conclusion that 'the B horizon of podzolized soils is not only a horizon of accumulation but also a horizon of transformation'. It is thus possible that

a certain amount of recombination has taken place among the various constituents giving rise to secondary minerals which may be removed from the colloidal state by the intense drying to which these sandy soils are subjected. Polynov (19) recorded the presence of a magnesium alumo-silicate paligorskite in the illuvial horizons of some Russian soils. According to Fersman (8) the formation of paligorskite in sandy soils is due to the interaction of colloidal alumina, silica, and magnesium carbonate. This is quite a reasonable explanation since the soil solution percolating down must contain a certain amount of these substances.

Adsorbed Bases and Acidity.

Except in the organic horizons the content of exchangeable bases is extremely low, and in many cases so small that their determination is difficult. This is found to be the case in most Scottish forest soils formed from non-basic rocks. Table X gives the amounts of exchangeable calcium and magnesium found in profile 43 together with the pH of each horizon. From the pH value it is evident that hydrogen must be the predominant cation in the adsorption complex.

The high exchangeable Ca and Mg in the A_0 and A_1 layers is probably partly due to the lower volume weight of these horizons. There is a slight increase in exchangeable Ca in the B horizon, but when dealing with such small quantities sampling errors may be sufficient to account for any small differences found.

TABLE X. *Adsorbed Bases and pH for Profile 43.*

Values expressed on an oven-dry basis.

Horizon.	A_0	A_1	A_2	B_1	B_2	B_3	C
Calcium	0·14% 7·0 m.eq.	0·06% 3·0 m.eq.	0·015% 0·8 m.eq.	0·021% 1·1 m.eq.	0·01% 0·5 m.eq.	0·016% 0·8 m.eq.	0·015% 0·8 m.eq.
Magnesium	n.d.	0·032% 2·6 m.eq.	0·012% 1·0 m.eq.	0·012% 1·0 m.eq.	0·011% 0·9 m.eq.	0·01% 0·8 m.eq.	0·01% 0·8 m.eq.
pH	3·75	3·92	4·34	4·48	4·54	4·83	5·15

In Table XI are given the amounts of exchangeable Ca and Mg found in profile 3. They follow the same course as those found in profile 43. The

TABLE XI. *Adsorbed Bases in Profile 3.*

Horizon.	A_0^3	A_2	B_1	B_2	B_3	C
Calcium	0·067% 3·35 m.eq.	0·25% 1·25 m.eq.	0·016% 0·8 m.eq.	0·013% 0·63 m.eq.	0·014% 0·7 m.eq.	0·032% 1·6 m.eq.
Magnesium	0·054% 4·42 m.eq.	1 m.eq.	..	..	..	..

larger amount of Ca found in the A_2 horizon may be due to the fairly high humus content of that layer. Except in the A_0^3 horizon the amount of magnesium was extremely small.

The pH values for some of the other soils are given in Table XII. From these it is seen that there is a general decrease in pH with increasing depth. The pH of the illuvial horizon generally approximates to a value of 4·5, this being about the point of complete precipitation of iron from solutions of its salts. The value, however, is liable to vary on account of interference from any humus substances present.

TABLE XII. *pH of Normal Podzols.*

Horizon.	A_2	B_1	B_2	B_3	C
Profile 42. .	4·22	4·54	4·56	4·62	4·92
„ 44. .	4·27	4·60	5·22	..	5·22
„ 27. .	4·56	4·77	4·99	5·04	5·12
Boulder till in No. 27 .	5·13	..	..	..	..

2. PEATY GLEY PODZOLS.

In Tables XIII, XIV, and XV are given the results of the mechanical analyses of profiles 41, 23, and 40, respectively. It is seen from these tables that the clay content of the eluvial horizon is always very low, and usually rises definitely on passing into the illuvial horizon. In the case of profiles 23 and 41 in which the eluvial horizon was divided it is observed that the lower of the two layers is somewhat richer in clay.

TABLE XIII. *Mechanical Analysis of Profile 41.*

Expressed as a percentage of air-dry fine earth (<2 mm.).

Horizon. *Fraction.*	A'_2–G^1 *12–23* *cm.*	A''_2–G *35–45* *cm.*	B_2 *46–56* *cm.*	B_3 *60–70* *cm.*
Coarse sand . . .	48·34	46·30	44·86	45·83
Fine sand . . .	32·23	29·67	28·68	28·47
Silt	7·6	12·10	15·15	12·38
Clay	7·9	10·80	10·53	11·75
Loss by soln. . . .	0·65	0·62	0·61	0·15
Moisture . . .	1·79	1·78	1·08	0·65

[1] The letter *G* is used to indicate the gleyed horizon.

This is probably due to the mechanical washing-down of clay from the upper layer, the hardpan preventing its removal to the lower horizons. In the case of profile 41 there is no difference in the clay contents of the lower A_2 and B_2 horizons. It is probable, however, that a mechanical analysis of the hardpan would show a sharp increase in clay. It could not be carried out owing to lack of material.

TABLE XIV. *Mechanical Analysis of Profile 23.*

Expressed as a percentage of air-dry fine earth (<2 mm.).

Horizon. / *Fraction.*	A'_2–G 11–17 cm.	A''_2–G 17–27 cm.	B_2 30–40 cm.	B_3 40–50 cm.	C 80–90 cm.
Coarse sand	60·73	30·00	36·02	45·03	45·26
Fine sand	15·50	44·40	35·60	30·40	24·94
Silt	7·05	6·65	12·15	12·15	17·70
Clay	4·25	7·75	7·30	9·10	11·70
Loss by soln.	0·38	1·21	1·17	0·81	0·13
Moisture	2·24	5·49	2·14	1·43	0·64

TABLE XV. *Mechanical Analysis of Profile 40.*

Expressed as a percentage of air-dry fine earth (<2 mm.).

Horizon. / *Fraction.*	A_2–G 7–17 cm.	B_1 17–23 cm.	B_2 23–33 cm.	B_3 40–50 cm.	C 70–80 cm.
Coarse sand	58·29	48·70	48·91	48·69	46·08
Fine sand	29·65	24·53	27·84	32·63	34·90
Silt	6·75	8·30	7·55	8·55	9·82
Clay	3·75	8·50	8·75	8·75	8·88
Loss by soln.	0·15	1·52	1·36	0·50	0·45
Moisture	1·10	5·10	4·34	1·40	0·92
Loss on ignition	4·70	13·53	9·36	2·80	2·59

In profile 41 the same general features are observed, the clay content being low in the eluvial horizon and rising sharply in the B horizon. An interesting feature of this soil is the large amount of humus which has been washed down into the lower layers. This is a very characteristic feature of the humus or peaty gley podzols as originally described by Frosterus (9).

As was observed in connexion with the normal podzols the mechanical fractions of the eluvial horizon are very light in colour and evidently have had a large portion of their iron content leached out. The fractions of the illuvial horizon are quite strongly coloured.

It is of interest to note that the red colour of the till is entirely due to the silt and clay fractions; the sands contribute the purplish tinge.

Analyses of the Clay Fraction.

From the analyses given in the following tables it is seen that the peaty gley podzols have undergone leaching just as strong as the normal podzols. In the case of profile 41 this is not brought out very well by the clay analysis owing to the absence of an analysis of the hardpan. The analyses of the other two profiles do bring out this leaching. It is especially marked in profile 40, there being a very abrupt fall in the SiO_2/R_2O_3 ratio. After this decrease the ratio gradually rises again.

In the discussion of the morphology of the soils, it was mentioned that there appeared to be two well-defined layers above the hardpan, but whether these were both eluvial horizons or not could not be proved without recourse to chemical analysis. The results for both profiles 23 and 41 definitely show that these two layers are eluvial, the lower one in 23 being slightly less leached than the upper. In profile 41 the reverse is the case, but the difference is slight.

TABLE XVI. *Clay Analysis of Profile 41.*

As a percentage of ignited clay.

Horizon.	A'_2–G *13–23 cm.*	A''_2–G *35–45 cm.*	B_2 *46–56 cm.*	B_3 *60–70 cm.*
SiO_2	46·01	45·45	41·90	48·68
TiO_2	1·52	0·91	0·70	0·52
Al_2O_3	37·44	36·51	39·97	37·28
Fe_2O_3	10·84	9·84	15·03	10·50
SiO_2/R_2O_3	1·75	1·87	1·44	1·86
SiO_2/Al_2O_3	2·08	2·18	1·78	2·19
SiO_2/Fe_2O_3	11·30	12·80	7·42	12·20

A possible explanation of this is that under the conditions associated with waterlogging there is a tendency for silica to pass into the colloidal state and to be leached out (23 a). This would lead to the relatively higher sesquioxide content in the upper part of the eluvial horizon.

TABLE XVII. *Clay Analysis of Profile 23.*

As a percentage of ignited clay.

Horizon.	A'_2–G *11–17 cm.*	A''_2–G *17–27 cm.*	B_2 *30–40 cm.*	B_3 *40–50 cm.*	C *80–90 cm.*
SiO_2	45·12	42·98	40·05	45·23	45·77
TiO_2	2·30	1·50	1·40	1·00	1·00
Al_2O_3	41·17	42·95	41·54	36·95	36·51
Fe_2O_3	6·63	6·53	9·72	14·30	9·17
SiO_2/R_2O_3	1·68	1·63	1·42	1·66	1·83
SiO_2/Al_2O_3	1·85	1·99	1·63	2·06	2·12
SiO_2/Fe_2O_3	18·10	17·50	10·95	8·40	13·27

In the illuvial horizon of profile 40 there is a very marked increase in the sesquioxide content. As in the case of the normal podzols, the alumina is carried much farther down the profile than the iron. In the case of profiles 41 and 23 the B_2 horizon has not been enriched to any extent in either iron or alumina. The conditions in the case of these soils seem to have favoured the accumulation of iron in the form of hardpan. Why this should be is not at all clear.

Although no signs of a high-water table were observed, the SiO_2/Fe_2O_3

TABLE XVIII. *Clay Analysis of Profile 40.*

As a percentage of ignited clay.

Horizon.	A_2–G 7–17 cm.	B_1 17–23 cm.	B_2 23–33 cm.	B_3 40–50 cm.	C 70–80 cm.
SiO_2	44·50	31·67	34·66	38·50	44·26
TiO_2	0·50	1·27	0·80	0·60	0·60
Al_2O_3	33·50	28·72	32·65	44·07	37·90
Fe_2O_3	10·03	24·87	22·30	13·07	12·00
SiO_2/R_2O_3	1·89	1·15	1·25	1·25	1·65
SiO_2/Al_2O_3	2·25	1·75	1·80	1·48	1·98
SiO_2/Fe_2O_3	11·80	3·38	4·13	7·84	9·81

ratio for the B_3 horizon of profile 23 indicates the possibility of its presence. It appears that slight leaching has taken place from the layer immediately below the hardpan, redeposition taking place in the next layer. It is always possible, however, that the enrichment is from below as has been suggested by Tamm (27).

Ultimate Analysis of Profile 41.

The results of an incomplete ultimate analysis of profile 41 are presented in Table XIX. Potash and soda were not determined.

TABLE XIX. *Ultimate Analysis of Profile 41.*

As percentages of ignited fine earth.

Horizon.	A_0 3–13 cm.	A'_2–G 13–23 cm.	A''_2–G 35–45 cm.	B_1 45–46 cm.	B_2 46–56 cm.	C 60–70 cm.
SiO_2	77·56	86·40	81·94	81·58	81·34	82·70
TiO_2	0·99	0·43	0·40	0·39	0·31	0·31
Al_2O_3	13·53	8·07	10·73	7·56	10·63	10·93
Fe_2O_3	3·03	2·16	2·55	7·23	3·34	3·04
CaO	1·61	0·37	0·33	0·37	0·21	0·23
MgO	1·65	0·38	0·38	0·54	0·22	0·52
Undetermined residue	1·63	2·15	3·67	2·33	3·95	2·27
Total	100·00	100·00	100·00	100·00	100·00	100·00
Moisture (105°)	39·94	1·79	1·78	3·25	1·08	0·65
Loss on ignition	41·88	3·54	3·64	2·66	2·54	2·76

Silica. As in the case of the normal podzols the peaty gley podzols have undergone strong leaching, the eluvial horizon showing a higher silica content than the other layers.

Sesquioxides. It is interesting to note that the alumina appears to have been removed to a very slight extent, especially from the lower part of the eluvial

horizon. Iron, on the other hand, has been strongly leached and redeposited mainly in the form of the hardpan (B_1). From the clay analyses it was seen that there was very little difference between the two layers into which the eluvial horizon had been divided. The ultimate analysis also shows this to be the case, if anything the upper portion being more strongly leached.

From the analyses there does not appear to be any accumulation of aluminium in the hardpan. It would probably be carried down to the B_2 horizon as is usual. As judged by the loss on ignition the humus content of the pan is low, the cementing of the sand grains must be due almost entirely to precipitated ferric hydroxide and other iron compounds.

Calcium and Magnesium. The high values for these constituents found in the A_0 horizon are probably partly due to the high organic matter content of this horizon and partly to the presence of unweathered coarse sand from disintegrating stones which are very common in the peat. There is really very little change on the whole in the content of these bases throughout the profile, but there is a slight increase in the CaO, and a sharp rise in the MgO content of the hardpan to be noted. The high magnesia content may be associated with the formation of secondary minerals of the paligorskite type. On the other hand, this higher base content may have been the reason for the precipitation of the iron. That the base status plays an important part in the precipitation is seen from the pH values for the illuvial horizons. In the case of the normal podzols the value was about 4·5. In the humus podzols it is a little higher, ranging from 4·7 to 5·0.

Adsorbed Bases and Acidity.

Like the normal podzols these peaty gley podzols are very acid and the content of exchangeable bases is extremely low except in the A_0 horizon. Table XX gives the content of exchangeable calcium and the pH of profile 41. The amounts of magnesium were too small for accurate determination.

TABLE XX. *Exchangeable Calcium and pH of Profile 41.*

Horizon.	A_0 *7–13 cm.*	A'_2–G *13–23 cm.*	A''_2–G *35–45 cm.*	B_2 *46–56 cm.*	C *60–70 cm.*
Calcium . .	0·1% 5·0 m.eq.	0·013% 0·65 m.eq.	0·011% 0·55 m.eq.	0·008% 0·4 m.eq.	0·026% 1·3 m.eq.
pH . .	4·26	4·82	4·88	5·01	..

3. PEAT GLEY SOILS.

In Table XXI are given the results of the mechanical analysis of the mineral horizons of profile 25.

There is a definite increase in the silt and clay content in passing from the gleyed horizon into the unaltered till. There is a possibility of a mechanical

TABLE XXI. *Mechanical Analysis of Profile 25.*

As a percentage of air-dry fine earth.

Horizon.	*G'*	*G''*	*C*
Coarse sand . .	39·25	48·16	47·50
Fine sand . .	39·33	37·82	25·02
Silt . . .	8·75	11·00	13·52
Clay . . .	12·60	12·50	14·30
Loss by soln. .	0·27	0·16	0·17
Moisture . .	8·75	4·38	6·66

loss of the fine fractions, since there appears to be a definite flow of water through the moss.

TABLE XXII. *Clay Analysis of Profile 25.*

As a percentage of ignited clay.

Horizon.	*G'*	*G''*	*C*
SiO_2 . . .	51·31	51·10	50·50
TiO_2 . .	n.d.	n.d.	0·57
Al_2O_3 . . .	37·77	36·07	40·55
Fe_2O_3 . . .	4·71	7·07	8·58
SiO_2/R_2O_3 . .	2·12	2·12	1·85
SiO_2/Al_2O_3 . .	2·30	2·39	2·10
SiO_2/Fe_2O_3 . .	18·20	12·10	9·80

That there is a decided chemical leaching is seen from Table XXII in which are given the results of the analyses of the clay fractions. Unfortunately these results do not bring out the proportion of ferrous iron in the clay, because from the colour of the horizons ferrous iron would appear to represent a considerable proportion of the total iron present. There is practically no change in the SiO_2/R_2O_3 and SiO_2/Al_2O_3 ratios; the SiO_2/Fe_2O_3 ratio, however, changes very sharply on passing from the G horizon into the till. The iron that is removed does not appear to be deposited in the underlying layers, in fact the iron content of the C horizon in this profile is smaller than that of the till underlying the peaty gley podzols. It would thus appear to be washed completely out of the soil.

As in the case of the peaty gley podzols both the peat and the mineral soil in these mosses are extremely acid, the pH being in every case below 5. Exchangeable bases are likewise very low, in no case did the amount of exchangeable Ca reach 1 milli-equivalent while magnesia was too small to be determined with any accuracy.

VI. DISCUSSION OF RESULTS.

It has been definitely established that the soils described all belong to the great group of podzolic soils which are subject to strong leaching from the upper mineral horizons, with the subsequent deposition of some of the leached substances at some depth from the surface. As a general rule, the bases are

leached first, iron next, while alumina and silica are the last to be removed. Phosphates usually move with the iron.

There are two important results of this leaching and deposition which are of great importance in the elucidation of forestry problems. The first is the progressive impoverishment of the upper mineral layer of the soil (i.e. the A_2 horizon), the second is the cementation of the illuvial horizon, or part of it, to form hardpan. These two results are essential features of the podzolization process, and usually bring about very marked changes in the surface vegetation. The impoverishment of the surface mineral layer leads to the invasion of the ground by a type of vegetation which makes small demands on the soil for mineral nourishment, with the result that when the plants die very little mineral matter is returned to the soil. The essential processes of podzolization, however, are not necessarily affected by this change in vegetation. When the cementation of the illuvial horizon has proceeded to such an extent that an impermeable layer has been formed, then both soil and vegetation undergo fundamental changes. The layers above the hardpan become waterlogged for long periods, peat formation sets in, and reduction processes predominate in the upper mineral layers. Thus the soil has ceased to be a normal podzol, for one of the essential conditions in the formation of normal podzols is good drainage. To this new type we have applied the term peaty gley podzol.

Plate II (*c*), illustrating the vegetation around profile 40, shows the great change which has taken place in the surface vegetation as a result of the impedance of drainage by the hardpan, together with a very poor soil.

An attempt was made to determine the amounts of 'available' potash and phosphate in the Teindland soils by the methods in use in the Macaulay Institute. The quantities obtained were very minute, in most cases being less than 1 mgm. per kilogram of soil. Since this was true of both the normal podzols, on which tree-growth is good, and the humus podzols on which growth is poor, it would appear as if the drainage is the determining factor for tree-growth in this case. Scots pine, of course, always prefers a sandy soil, while larch and spruce thrive better on loams in which the moisture content is higher.

Since it appears that drainage is the main factor governing tree-growth on the peaty gley podzols, the removal of the cause of the bad drainage would appear to be the first necessity. The removal of the hardpan presents many difficulties, and a number of methods for this have been proposed. Owing to the impossibility of employing chemical methods, reliance must be placed on physical methods. Deep ploughing with breaking-up of the hardpan at the same time would appear to be a satisfactory method, but it would be limited to soils in which the pan was fairly near the surface. The general nature of the soil itself and the surface of the ground must be taken into consideration. An attempt was made at Teindland to cut some open drains with a Henderson plough, but owing to the stony nature of the surface soil the project failed. Ordinary ploughing has been used with marked success in establishing young trees, but in addition to ploughing some treatment with artificial fertilizers

is necessary, phosphates being chiefly used. By simple ploughing the aeration of the surface soil is improved and the mixing of the peat with the A_2 horizon will improve the texture of the soil. The trees, once they are properly established, may be strong enough to penetrate the hardpan and so break it up. The improvement in the aeration of the surface may have a much greater effect in softening the hardpan. It was observed that the hardpan exposed in ditches was much softer than that found in freshly-dug pits.

Another method of breaking up the pan which has been used is by means of explosives. The use of an explosive which has a good lateral thrust as well as vertical would certainly soon break up the pan sufficiently to allow root penetration.

After breaking up the pan some measures to prevent its formation again, which might take place fairly rapidly under such acid conditions, would have to be considered. The use of basic manures, such as basic slag, would have the desired effect, and in addition would supply a nutrient in which the soil is deficient. Liming would not be so beneficial to conifers as it would reduce the acidity too much, and these trees require a fair degree of acidity for proper growth.

The improvement of impoverished podzolized soils might also be carried out by planting birch. Tamm (28) has described the reversion to brown earth of a podzol which was planted with birch. The litter from birch is much richer in minerals than coniferous litter, so that an enrichment of the surface layers of the soil takes place. This enrichment would be effective in two ways. It would increase the degree of saturation of the soil adsorption complex and so prevent its further destruction, and it would also improve the texture of the surface horizon, since the litter decomposes much more readily. It might also be advantageous to plant birch in mixture with conifers, the base content of the surface horizons of the soil being then kept up during the whole period of the crop. Up to the present it has been the general practice in forestry to map areas as plantable or otherwise, principally on the basis of surface vegetation, elevation, and exposure, without taking into detailed consideration the properties of the soils which underly the vegetation. This may be quite a successful method in many ways, but there are cases in which the ground would be called plantable as judged by the vegetation, &c., and yet the soil would not support a vigorous forest. Taking profiles 40 and 41 or 23 as examples, we see that the absence of hardpan in 40 would enable the tree roots to penetrate well into the soil, whereas in the case of 41 or 23 the hardpan would very soon hold up tree growth, yet the vegetation is the same for all these soils. A soil survey would indicate fairly accurately the boundaries of the various soil types, and when suitable methods have been evolved it will also be possible to make some statement as to the type and amount of manures required for the establishment of the young trees. Since this work has only begun in Scotland, it will require intensive examination of the various soil types and the conditions of their formation and development before a sound relationship between Soil Science and Forestry can be established.

SUMMARY.

From a study of the surface features of the Teindland Forest it is seen that it may be divided into three geomorphological elements, all of these being due to the effect of the third ice sheet which covered the north-east of Scotland. The soils and vegetation are very closely connected with the surface features, although these do not appear to have played a predominant part in the development of the soils except in one case. The soils have been classified into three main types: (1) normal podzols formed from fluvio-glacial sands, (2) peaty gley podzols formed from boulder till, and (3) peat gley soils on boulder till. Profile descriptions of examples of each of these types are given, followed with chemical and mechanical analyses of the various horizons. The analysis of clay fractions is shown to be very useful in studying the development of the soils. The peat gley soils owe their present features to the presence of an extremely compact and continuous hardpan which has impeded drainage and led to peat formation setting in. The vegetation on these soils is of a very inferior type, and tree growth is very poor. The vegetation of the normal podzols is of a much better standard and tree-growth (Scots pine and larch) is very good.

The general effects of podzolization and hardpan formation in relation to afforestation and methods used for bringing about soil improvement are discussed.

I wish to express my indebtedness to the late Professor K. K. Gedroiz and to Professor B. B. Polynov for granting me the opportunity to become acquainted with the methods used for soil investigation in Russia.

The facilities afforded by various members of the Forestry Commission staff during several visits to the Teindland Forest have been of great value, while thanks are due to Dr. W. G. Ogg for his unfailing interest in the present work.

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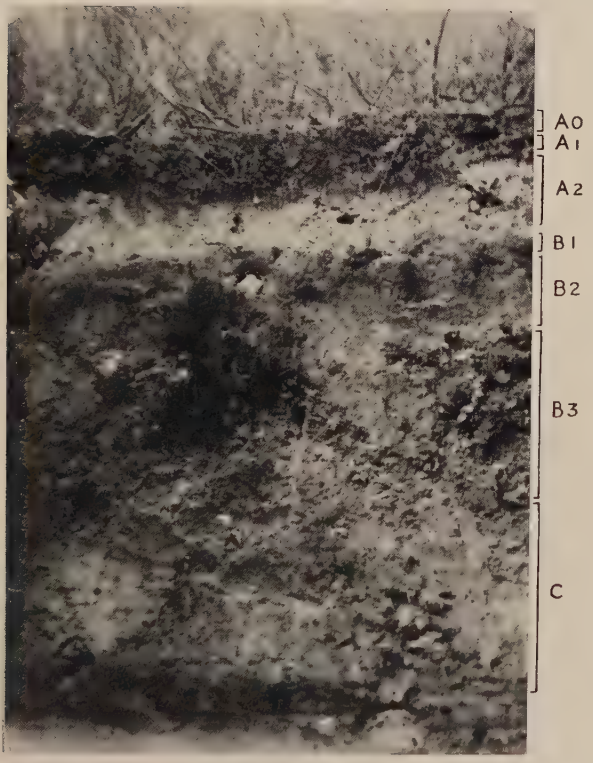
(*a*) Vegetation at Profiles 42 and 43



(*b*) Profile 43

PLATE I

(*c*) Vegetation at Profile 40

(*d*) Vegetation at Profile 25

PLATE II

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THE FORM OF THE STEM IN CONIFEROUS TREES[1]

(Continued)

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THE last article in this series dealt with the distribution of form-classes within stands, and with the mean form-class of species and of individual crops, and it went on to investigate and discuss root swelling and bark thickness which are factors of very great importance. The next step is to find out some convenient yet accurate method of determining the form-class of individual trees because, in the absence of such a method, it is impossible to apply in practice any of the knowledge which has been acquired. The determination of the form-class of individual trees is a problem that falls naturally into two parts, according as to whether the trees are felled or standing, and it will, therefore, be discussed in two separate sections.

Determination of Form-class of Felled Trees. Trees are grouped together into form-classes in accordance with their absolute form quotients; that is to say, all trees with the same under-bark relationship between the girth at breast height and that at midway between breast height and the tip are placed together in one form-class. Thus in order to determine the form-class to which an individual tree belonged we would have to obtain measurements at breast height, and at the mid-point of the stem above breast height and then make allowance for bark thickness at these points of measurement, and for root swelling at breast height. As this would prove a laborious proceeding in practice, it was felt that some simpler method was required, and in consequence a table was prepared showing for trees of different form-classes the over-bark girths at breast height and at the mid-point of the stem above breast height. The over-bark values were obtained by making the proper allowances for bark thickness and for root swelling at breast height. An example of one of these tables is given in Table XLIII, which has been prepared for Norway spruce. From this table, once the over-bark girths at breast height and at the mid-point of the stem above breast height are known, it is possible to read off the form-class without further trouble, but no general table of this kind can be prepared for use with all species on account of the differences between the species in bark thickness and root swelling. A separate table is therefore necessary for each species.

The use of the table in practice is, of course, attended by certain risks and inconveniences. In the first place, it is based on a single measurement on the stem above breast height and this may lead to errors, particularly on young and irregularly shaped stems. Secondly, it applies to individual trees' figures

[1] Continued from *Forestry*, vii, No. 2, pp. 121–9.

for bark thickness and root swelling which are based on the averages of large numbers of trees, and as a result the form-class as given by the tables may differ from the true form-class. With a large number of trees these errors would no doubt cancel each other out to a considerable extent, and a fairly good approximation to the average form-class would be obtained, but it must be emphasized that to use the tables for the determination of the form-class of an individual tree will always be a rather risky proceeding.

Some slight inconvenience may be caused to workers in the forest by having to measure at the mid-point of the stem not above ground level, but above breast height, and after the total length of the tree has been measured a calculation is required to give the distance from the root-cut of the upper point of measurement. But it is quite an easy matter to prepare a simple table to show the distance from the butt-end of the tree of the point of measurement on trees of different lengths. The following is an example:

Length to tip.	*Breast height.*	*Mid-point of tree above breast height.*
feet.	*feet.*	*feet.*
40	4·25	22·125
60	4·25	32·125
80	4·25	42·125
90	4·25	47·125

Or a simple mental calculation can be made:

$$\text{Distance of mid-point from butt} = \frac{(\text{Total height to tip} + 4\frac{1}{4})}{2} \text{ feet}$$

The figures given in Table XLIII for Norway spruce have been tested in a felled plot of this species. One hundred and sixty-seven trees were chosen

TABLE XLIII. *Determination of Form-class. Norway Spruce.*

Breast-Height Girth. (*O.B.*)	*Girth (over bark) at mid-point between breast height and tip (inches).*												
	8	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
	Form-class												
16	·525	·575	·650	·700	·775	·800	..	..	..	..	..	..	..
18	·450	·525	·575	·625	·675	·725	·775	..	..	..	..	..	..
20	..	·475	·525	·575	·625	·650	·725	·775	·825	·850	..	..	..
22	..	·450	·500	·525	·575	·600	·675	·725	·775	·800	·850	..	..
24	..	..	·475	·500	·525	·550	·625	·650	·700	·750	·800	·825	·850
26	..	..	..	..	·475	·500	·575	·600	·650	·700	·725	·750	·800
28	..	..	..	..	..	·475	·525	·575	·600	·650	·675	·725	·750
30	..	..	..	..	..	·450	·500	·525	·575	·600	·650	·675	·700
32	..	..	..	..	..	..	·475	·500	·525	·575	·600	·625	·650
34	..	..	..	..	..	..	·450	·475	·500	·550	·575	·600	·625
36	..	..	..	..	..	..	..	·450	·475	·500	·550	·575	·600
38	..	..	..	..	..	..	..	..	·450	·475	·525	·550	·575
40	..	..	..	..	..	..	..	..	..	·450	·500	·525	·550

Breast-Height Girth. (O.B.)	*Girth (over bark) at mid-point between breast height and tip (inches).*											
	21	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*
	Form-class											
24	·875	..	..	..	..	..	..	..	..	..	..	..
26	·850	·875	..	..	..	..	..	..	..	..	..	..
28	·800	·825	·875	..	..	..	..	..	..	..	..	..
30	·750	·775	·825	·850	..	..	..	..	..	..	..	..
32	·700	·725	·750	·800	·825	·875	..	..	..	..	..	..
34	·650	·675	·700	·750	·775	·825	·850	..	..	..	..	..
36	·625	·650	·675	·725	·750	·775	·800	·825	·875	..	..	..
38	·600	·625	·650	·675	·700	·725	·750	·800	·825	·850	·875	..
40	·575	·600	·625	·650	·675	·700	·725	·750	·775	·800	·825	·850

at random and their form-class determined with the help of the table by over-bark measurements at breast height and at the mid-point of the stem above this point; the form-class was also obtained by complete under-bark measurements.

With the tables the average form-class was determined as 72·1, whereas with complete measurement the average came to 73·3, and although both figures come within the same general form-class, namely 72·5, the figures given by the tables are appreciably lower. This difference is due very largely to the abnormally high root swelling in the plot which was examined.

Determination of Form-class of Standing Trees. The problem of how to determine the form-class of standing trees has been solved in Sweden by the use of the form-point method which is now well known all over the world. Between the position of the form-point, which is, broadly speaking, the point in the crown corresponding to the centre of gravity, and at which the wind pressure may be considered as acting, and the form-class a definite relationship has been established, and in order, therefore, to discover the form-class it is necessary only to make an estimate of the percentage of the total height at which the form-point is located. This can be done readily with the help of a Christen's hypsometer suitably graduated.

This method is so simple and offers so many attractions that it is a matter of regret that it has not been found possible to make general use of it in this country. In our dense even-aged plantations it is difficult to obtain a good view of the crown of individual trees, and to decide on the position of the form-point.

The method which we use in sample plot work has been described elsewhere (1). Briefly, it consists in making measurements on the lower part of the stem and in using one of Behre's theoretical curves to give the girths on the upper part of the stem which cannot be obtained directly. The height of the standing tree is obtained with a hypsometer, and girths are measured at breast height and at 5, 10, 15, &c., per cent. of the height above breast height, under-bark values being obtained with the help of the bark-measuring instrument. The girth quotients are calculated and plotted in the usual way and root swelling

eliminated. A fresh curve is drawn and prolonged until it cuts the line representing the mid-point between breast height and the tip of the tree, and its value at this point gives the form-class. This method, though slow, can be used with safety in estimating the form-class of individual trees.

Determination of Volume. The use of form-classes introduces into the methods of volume-determination an element of greater precision, as trees with different rates of taper are no longer grouped together by size alone. An attempt was therefore made to prepare volume tables based on form-class in the expectation that these, if carefully used, would be of some help in the estimation of volume.

In the third of this series of articles it was shown that, after allowance had been made for root swelling, the form of the stem under-bark was substantially the same for all the principal coniferous trees, and this might have led one to expect that one set of volume tables would have been sufficient for all species. But root swelling varies so widely from species to species, particularly in the larger trees, that if a set of general tables were prepared it would be necessary to apply to them a series of factors to make the appropriate corrections for the different species. In addition, convenience in working demands that under-bark volumes should be shown against over-bark girths, and this introduces another variable, namely, the bark thickness. In the circumstances, therefore, it was decided to prepare provisionally form-class volume tables for Norway spruce, and if these proved satisfactory to proceed to the preparation of tables for other species.

From the point of view of this investigation, the stem of a tree is divided into two parts, that above breast height, and that below this point of measurement. Hitherto in these articles we have ignored the latter section, but it now becomes necessary to take it into consideration and to calculate its volume separately. This section was cubed in one length by Huber's formula, the mid-point being at 2 feet 1½ inches above ground. The girth at this point was obtained by drawing a curve to represent the actual form of the stem under-bark including root swelling, which after all represents material put on by the tree, and by prolonging this curve downwards below breast height until the required point of measurement was reached. Girths at this point had already been measured in the forest from time to time on numbers of trees, and these data were used as a check on the values obtained.

The calculation of the volume in the portion of the stem above the breast-height mark was made slightly more difficult on account of the need for measuring not the total content to the tip of the tree, but the content down to a 3-inch diameter over-bark, and this required as a first step the determination of the timber-point on trees of different size, height, and form-class. The procedure was as follows. The under-bark girth corresponding to a diameter over-bark of 3 inches was divided by the *normal* breast-height girth and a girth quotient obtained. The height quotient corresponding to this girth quotient was then read from Behre's curves for the different form-classes, and a series of values obtained. Thus for form-class 60·0 the timber-point

on trees of 16-inch girth was found to be located at 48 per cent. of the length above breast height, while for form-class 65·0 it was situated at 54 per cent.

In our ordinary work, if we have a tree with a timber length of 48 feet, we measure it in four lengths of 10 feet and one of 8 feet, and in the calculation of the volume we use the girths and sectional areas at 5, 15, 25, 35, and 44 feet, respectively (2). So, in obtaining the volumes for the tables a similar method was employed, and with a tree of 16-inch girth and form-class 60·0 when the timber-point is situated at 48 per cent. of the height above breast height, the points of measurement were taken at 5, 15, 25, 35, and 44 per cent., the lengths of the sections being 10, 10, 10, 10, and 8 per cent., respectively. The lengths of the 10 per cent. sections thus vary with the length of the tree; in a 40-foot tree they are 3·575 feet long, whereas in a 90-foot tree the length is 8·575 feet. The girths at the various points of measurement are obtained in the usual way from the curves for the different form-classes. The volume of the tree is then obtained by summing the sectional volumes above breast height, and adding to this sum the volume of the butt below the breast-height mark.

In this method of volume calculation, the figures are obtained from the theoretical curves, and it may be objected that since the data for Norway spruce do not fit these curves exactly, there may in consequence be errors of some magnitude. In an earlier article it was seen that Norway spruce fitted Behre's curves quite closely, except in the upper parts of the stem, and therefore any serious errors would be confined to those parts. But by measuring to a 3-inch diameter it becomes possible to exclude a considerable part of the top length and thus to reduce the risk of error.

The tables which are given here have been tested on 400 trees of Norway

TABLES XLIV–LII. *Form-class Volume Tables for Norway Spruce.*

Form-class 60·0.

Breast-Height Girth. (*O.B.*)	*Height of Tree* (*feet*).					
	40	50	60	70	80	90
	Volume-under-bark (*cubic feet*).					
16	1·9	2·3	..	..	..	..
18	2·6	3·1	..	..	..	..
20	3·3	3·9	4·6	..	..	..
22	4·0	4·8	5·7	6·4	..	..
24	4·8	5·8	6·7	7·7	..	..
26	5·6	6·8	7·9	9·1	10·3	..
28	6·4	7·9	9·3	10·7	12·0	13·4
30	7·5	9·0	10·6	11·8	13·3	14·8
32	8·6	10·3	12·2	14·0	15·8	17·6
34	..	..	13·8	15·8	17·8	19·9
36	..	..	15·4	17·7	20·0	22·3
38	..	..	..	19·8	22·3	24·8
40	..	..	..	22·1	24·9	27·7

spruce, and the total volume which they gave differed from that obtained in the usual way by −1·85 per cent. This is a satisfactory result.

Volume tables are given for Norway spruce for form-class 60·0 to form-class 80·0, and they show under-bark volumes measured down to a 3-inch diameter for trees of 16 to 40 inches in girth at breast height, and from 40 to 90 feet in height. Volumes are given in cubic feet, true girth measure. Heights are grouped in 10-foot classes, the 40-foot class, for example, including all trees with heights between 35 feet and 45 feet.

Form-class 65·0.

Breast-Height Girth. (*O.B.*)	*Height of Tree* (*feet*).					
	40	*50*	*60*	*70*	*80*	*90*
	Volume-under-bark (*cubic feet*).					
16	2·0	2·5	..	..	..	..
18	2·7	3·4	..	..	..	..
20	3·4	4·2	4·9	..	..	..
22	4·2	5·1	6·1	7·0	..	..
24	5·0	6·2	7·3	8·3	..	..
26	6·0	7·3	8·6	9·8	11·2	..
28	6·9	8·4	10·1	11·4	13·0	14·4
30	8·0	9·8	11·4	12·9	14·7	16·5
32	9·2	11·2	13·2	15·3	17·3	19·2
34	..	..	14·9	17·2	19·4	21·7
36	..	..	16·7	19·4	21·7	24·3
38	..	..	..	21·6	23·9	26·7
40	..	..	..	24·1	26·4	29·8

Form-class 70·0.

Breast-Height Girth. (*O.B.*)	*Height of Tree* (*feet*).					
	40	*50*	*60*	*70*	*80*	*90*
	Volume-under-bark (*cubic feet*).					
16	2·3	2·8	..	..	..	..
18	3·0	3·7	..	..	..	..
20	3·8	4·6	5·4	..	..	..
22	4·6	5·6	6·6	7·6	..	..
24	5·5	6·7	7·9	9·1	..	..
26	6·5	7·9	9·3	10·7	12·1	..
28	7·5	9·1	10·8	12·4	14·0	15·7
30	8·5	10·6	12·4	14·4	16·2	18·1
32	9·9	12·0	14·3	16·8	19·0	20·9
34	..	..	16·1	18·9	21·5	23·5
36	..	..	18·0	21·2	24·0	26·4
38	..	..	..	22·8	25·6	28·8
40	..	..	..	25·5	28·7	32·1

Form-class 75·0.

Breast-Height Girth. (*O.B.*)	*Height of Tree* (*feet*).					
	40	50	60	70	80	90
	Volume-under-bark (*cubic feet*).					
16	2·5	3·0	..	..	..	..
18	3·3	4·0	..	..	..	..
20	4·1	4·9	5·9	..	..	..
22	4·9	6·0	7·1	8·5	..	..
24	5·9	7·2	8·5	10·2	..	..
26	7·0	8·5	10·2	11·8	13·2	..
28	8·1	9·8	11·9	13·7	15·2	17·1
30	9·3	11·3	13·4	15·8	17·4	19·6
32	10·7	12·9	15·4	18·3	20·2	22·6
34	..	..	17·3	20·6	22·7	25·4
36	..	..	19·3	23·1	25·4	28·4
38	..	..	..	25·6	28·0	31·2
40	..	..	..	28·6	31·0	34·6

Form-class 80·0.

Breast-Height Girth. (*O.B.*)	*Height of Tree* (*feet*).					
	40	50	60	70	80	90
	Volume-under-bark (*cubic feet*).					
16	2·8	3·4	..	..	..	..
18	3·6	4·4	..	..	..	..
20	4·5	5·4	6·5	..	..	..
22	5·4	6·6	7·6	9·5	..	..
24	6·5	7·8	9·1	11·4	..	..
26	7·7	9·2	11·3	13·3	14·5	..
28	8·8	10·6	13·1	15·3	16·7	18·6
30	10·1	12·2	14·5	17·6	19·1	21·4
32	11·5	13·8	16·5	20·0	21·7	24·3
34	..	..	18·6	22·5	24·5	27·5
36	..	..	20·8	25·2	27·4	30·7
38	..	..	..	28·0	30·4	34·0
40	..	..	..	31·2	33·8	37·9

SUMMARY.

1. A brief account is given of the progress and development of research into the form of the stem in conifers, and the nature of the problem in Great Britain is discussed.

2. The material on which this investigation has been based consists of approximately 2,500 trees of twelve different species. These trees have been obtained mainly from permanent sample plots in all parts of the country.

3. The form of the stem in the various conifers agrees sufficiently well with Behre's theoretical curves except in the upper parts of the stem, where there are considerable differences. These differences are more pronounced in young trees which are more irregular in form than older trees.

4. After bark thickness and root swelling have been allowed for, the under-bark form of the different conifers is similar.

5. Variations in form-class within species, and within individual stands, are discussed. The material is, however, insufficient to permit of the drawing of any definite conclusions.

6. Tables are given to show the amount of root swelling at breast height, and to show the thickness of bark at different points on the stem in the various species. A table is given to aid in the determination of the form-class of Norway spruce and form-class volume tables for this species are published.

I have to express my thanks to the Forestry Commissioners for permission to publish the data on which this investigation has been based.

LITERATURE REFERENCES

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(2) —— 'Sample Plot Methods in Great Britain.' *Empire Forestry Journal*, x. 2, 1931.

A PRELIMINARY REPORT ON A CYTOLOGICAL METHOD OF DISTINGUISHING *SALIX ALBA* VAR. *COERULEA* FROM CLOSELY RELATED SPECIES, VARIETIES, AND HYBRIDS

BY J. WILKINSON

DURING the last few months a close study has been made of the cytological behaviour of *Salix alba* var. *coerulea* (the 'cricket-bat willow') and certain other *alba* varieties, with hybrids involving *alba* and *fragilis*, in the hope of obtaining a means of distinguishing between the true cricket-bat willow and other similar types.

Up to the present, a study of the reduction divisions in the developing flower has not yielded very encouraging results, but certain facts have come to light about the chromosomes of the somatic complement, from the root tips, which may prove valuable, at least as a check, in the recognition of *Salix alba* var. *coerulea*. A distinction on somatic lines is, in any case, to be preferred on the score of convenience, for the members of the group of willows in question will root in water at practically any time of the year, although the most favourable period is from February to the beginning of April. Reduction material can, of course, only be obtained during a very limited period in the spring.

Several difficulties have been encountered in the preparation of the material for cytological study, and certain modifications in technique have been employed in order to overcome these obstacles. Firstly, it was found that of the fixatives tried (Langlet, Flemming, Regaud, Benda, Delaunay, and 2 BE) Langlet gave superior results, because its use tends to swell the chromosomes to a slight extent, thus emphasizing the constrictions. Secondly, it was found necessary to modify the staining technique so as to minimize the staining of the cytoplasmic background. In the Salices, due to the presence of tannin and like substances, the protoplasmic background, with any combination of fixing and staining, tends to be troublesome, and the difficulty is increased because of the small size and large number of the chromosomes. The chief modifications employed in staining were alterations in the periods of immersion in both Heidenhain's haematoxylin and iron alum, so that by the relatively greater destaining of the cytoplasm the chromosomes, and particularly the satellites, showed up more clearly. For the same reason it was also found better not to employ any counter-stain in the clove-oil used for clearing.

All the *Salix alba* varieties and hybrids involving *fragilis* examined during this preliminary investigation showed a somatic complement of 76 chromosomes, so it is impossible to segregate *alba* var. *coerulea* on the basis of number alone.

A critical examination of the chromosomes of the *alba* varieties so far

examined seems to indicate that the complement is the same throughout from the point of view of general morphology. Evidence derived from the examination of a large number of somatic metaphase plates, however, suggests that the differences between the *alba* varieties can, to some extent, be correlated with the number of satellites. All of the 76 chromosomes in the *Salix alba* complement are small, and the majority appear to be individually indistinguishable on morphological grounds; it has, however, been found possible to pick out five characteristic pairs of chromosomes from the *alba* plate (whatever the variety):

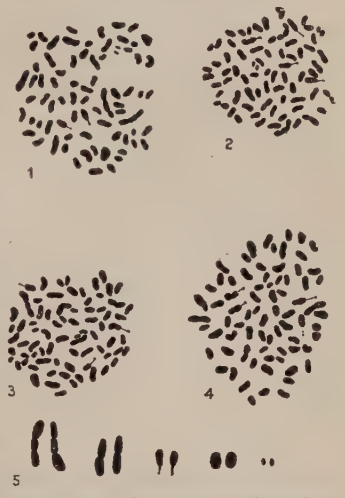
(1) A pair more than twice the average length, and showing two constrictions in each chromosome.

(2) A pair almost twice the average length, and with one constriction.

(3) A pair of short, constricted chromosomes, which are always satellited in any *alba* complement so far examined.

(4) A pair of almost oval chromosomes, wider than the average; their presence was at first thought to be an accident of the fixation or staining technique, but their constant recurrence in a large number of plates seems to leave little doubt as to their characteristic nature.

(5) A pair of extremely small, yet very sharply-defined chromosomes, less than half the average length, and always occurring side by side in the metaphase plate.



FIGS. 1–4. Chromosome plates from root tips × 2,000. (1) *Salix alba* v. *coerulea*, (2) *S. alba*, (3) *S. fragilis* × *alba*, (4) *S. fragilis*.

FIG. 5. Characteristic pairs of chromosomes of *S. alba* from Fig. 1 at a magnification of 4,000.

Fig. 1 illustrates a complete somatic plate of *Salix alba* var. *coerulea*. In Fig. 5 the pairs above described, drawn to a larger scale, are figured in the order mentioned.

Salix alba var. *coerulea* showed only two chromosomes with satellites, while the other *alba* complements examined showed at least four; these were the pair referred to in (3) above. In a typical *Salix alba* another satellited pair appeared, the chromosomes of which were longer than the last mentioned, were unconstricted, and the satellites more prominent (see Fig. 2).

In *Salix fragilis* there were no doubly constricted chromosomes like pair (1) of the *alba* complement, but there was a pair with a length greater than twice the average, and possessing one constriction. Four satellites, at least, were present on the *fragilis* somatic plates. These were attached to chromosomes of approximately the average length, one pair having a median constriction, and the other not obviously constricted (Fig. 4).

The attempt to identify these recognizable chromosomes of *Salix alba*

and *Salix fragilis* in the hybrids of the *viridis* type has met with some success. An examination of the somatic complements of the range of willows sent from Mr. Amos's plantations has shown in all cases but one the presence of both *fragilis* and *alba* chromosomes. One of these is illustrated in Fig. 3. In one tree, however, the somatic complement was cytologically indistinguishable from *Salix alba* var. *coerulea*. Root tips from five of those from Liss, Hants, all showed the *fragilis-alba* nature in the somatic complement.

It may be mentioned that there are some indications that the nature of the cytoplasmic background might be helpful in verifying the results arrived at on the grounds of morphology alone.

In conclusion, it may definitely be stated that there are indications of the possibility of separating *Salix alba* var. *coerulea* from closely related stocks on cytological grounds. At this stage one cannot go farther, because only a limited amount of the material has been examined; it may be that the further examination of *coerulea* from different localities will yield different results, and only repeated testing can reveal the worth of the conclusions so far reached. Colonel Pratt, in the *Quarterly Journal of Forestry*, January 1934, drew attention to the fact that the Essex growers of cricket-bat timber believe a certain strain to be more susceptible to 'butterfly marking', and if the existence of well-defined strains within the variety *coerulea* is a likelihood, then it is possible that variations in the chromosome morphology may be found.

So far as the work has gone, it seems that the cytological results will be of some service in providing a check on conclusions arrived at by other means, because the nature of the material and the delicacy of the distinctions (especially where these depend on satellite determination) prevent absolute reliance being placed upon them. Nevertheless, in conjunction with evidence from other sources, the results obtained may be of value.

It is hoped that the opportunity will be provided in the near future to collect further evidence along the lines indicated, and to amplify the information already obtained.

This investigation has been carried out in the Department of Botany, Armstrong College, Newcastle-on-Tyne, and I wish to thank Professor J. W. Heslop Harrison for facilities for carrying out the work. I should also like to thank Dr. J. Burtt Davy for supplying most of the willows and Dr. K. B. Blackburn for help during the progress of the work.

THE FASCIST GOVERNMENT AND THE RESTORATION OF ITALIAN FORESTS[1]

BY PROFESSOR DR. ALDO PAVARI

(Director of the Royal Experimental Station for Silviculture, Florence)

1. *The Forest Problem in Italy.* Of about 31 million hectares, the total area of Italy, only a little over 2½ millions are unproductive, that is, are occupied by water, buildings, roads, or are situated on ground absolutely sterile by nature, such as the high mountain tops above the upper limit of vegetation. The remaining area extending to 28½ million hectares is productive, and gives a return more or less high. Of this area, 53·8 per cent. is under agriculture, 26·7 per cent. is pasture land or untended ground which is put to use as pasture, and 19·5 per cent., or rather more than 5½ million hectares, is covered by forest. Thus the area which is not under agriculture occupies less than half (46·2 per cent.) of the area available for production, and of this only two-fifths is forested, the remaining three-fifths bearing no crops of trees. This is of great importance for a mountainous country like Italy, which has vast areas subject to erosion as a result of the peculiar geological formation and which, at the same time, has an irregularly distributed rainfall. A general survey of soil conditions in Italy shows that, while the plains are intensively cultivated and the hills fertile with vineyards, olives, and other tree crops, the mountains have scarcely any woods and are generally in a low state of productivity. The so-called 'productive mountain pastures' are often nothing more than coppices where constant grazing leads to progressive degradation and erosion of the soil, and thus the importance of erosion and floods increases from year to year with tragic consequences for the mountains themselves as well as for the plains and hills below.

The disastrous scouring of the torrents, the landslides, and the floods on mountain streams and on the great rivers brought about by the increase in alluvial matter brought down from the mountains make a sad story of constant destruction of wealth.

The small area given over to forestry and the areas occupied by coppice which is good only for fuel and for charcoal, areas which are great in comparison with those under high forest which alone can produce wood suitable for works necessary to the development of the national economy, are all conditions contributing to the problem before foresters in Italy. These conditions also make it necessary to import large quantities of wood from abroad, especially building constructional timbers, and pulp wood for the manufacture of paper and cellulose.

This is not the time to explain the causes which have led to the situation

[1] The Society is indebted to Miss Margaret Nelson, St. Hugh's College, Oxford, who translated this article from the Italian.

which has just been described. The age-old history of Italy is a history of deforestation dating back to the invasions of the barbarians after the fall of the Roman Empire, to the days of strife between feudal lords and peasantry in the Middle Ages, to the wars in which armies and mercenary bands took part, wars which followed each other throughout the centuries from the Middle Ages to the beginning of the nineteenth century. As a result, when the Kingdom of Italy had finally been formed in 1870, after the heroic wars of Independence, the forest wealth of the country had already been greatly reduced, and the erosion and devastation of the mountains, the floods of the rivers, and the spread of malaria-infested marshes by the sea-shore had all become of great importance. The country, worn out by heavy fighting, poor in its most essential needs, could not spare any large sums of money for reforestation. On the contrary, it was only through the intervention of Luigi Luzzatti that the few remaining state forests were saved, forests which were about to be sold to help to replenish the Treasury. The destruction of large oak woods, however, could not be prevented at the time of railway development, and in Sardinia whole forests were given up to the company which built the first railways.

In the meantime, the population which in 1872 amounted only to 26 millions had increased by 1882 to 28½ millions, and in 1901 to 32½ millions with 133 inhabitants per square kilometre. In 1911 there were nearly 35 million people in Italy with 202 inhabitants to the square kilometre.

As a result, in the first decades of its existence the new Kingdom of Italy saw its population increase with great rapidity in a country poor in essentials, and given over to agriculture on a soil of which two-thirds was mountainous and of low fertility. Although between 1900 and the outbreak of the European War the growing population had found an outlet in emigration (during 1913 over 800,000 Italians had to leave their country in order to seek their bread abroad), at the same time the dense population represented one of the most formidable factors in the progressive destruction and thinning-out of the small areas of forest in the country. In southern Italy and in the islands especially, the population pushed out by malaria which made the sea-shore and the plains uninhabitable had to seek refuge and subsistence in the mountains, destroying the woods in order to grow wheat and, above all, in order to find grazing for their cattle. This struggle between, on the one hand, the field and the pasture, and on the other, the forest, went all the more in favour of the former, because the lack of roads and the configuration of the country reduced the value of wood almost to nothing, and made difficult the transport of foodstuffs from the plains.

The conditions of ownership of the forests tended also to lead to their defeat in the struggle against the pressure of a population which was seeking food. In fact, State-owned forests at the time of the establishment of the Kingdom were small and amounted to only 193,000 hectares. The collective properties of the communes and of the public 'Enti' (communities) were very extensive, as they still remain, especially in central and southern Italy. These properties are subject to rights exercised by the civil population as a result of

historical precedent, rights to gather wood, to graze, and to plough. It is precisely in the areas belonging to the 'Enti', areas which represent one-third of all the woods and pastures of Italy, that the distressing consequences of an unchecked freedom are chiefly noticeable.

2. *Italian Forest Policy from 1887 to the March on Rome (1922).* The situation which has been outlined above could not but concern the Italian Government from the very inception of the new kingdom and in 1877 the first Italian forest law was passed. This replaced the legislation which had been in force until then in the various Italian states. The law of 1877 permitted the intervention of the State only on behalf of those forests of which the protection was of public interest, but left complete liberty of management in the others. This distinction was made on an ecological-agricultural basis according to the upper limit of the chestnut (*Castanea vesca*). That is to say, the legislature admitted that up to where the cultivation of the chestnut was possible in the mountains, the soil was of sufficient fertility for agriculture and consequently the landowner could, if he wished, replace his woods with other kinds of cultivation and vice versa. Above the chestnut zone, it was necessary to control the liberty of the owner and to introduce the forestry bond. The word bond means a series of limitations of the power of forest control; that is, tillage in pasture and woodland was forbidden, and the uses to which woods, pastures, &c., were put were regulated. The aims of the law were, as we have said, purely hydrogeological, its nature chiefly negative, the prevention of deforestation rather than the encouragement of reforestation, and the prevention of the development of agriculture in mountain lands.

The application of this law in the hands of the Royal Department of Forestry did not lead to satisfactory results in spite of the industry and self-sacrifice of the forestry staff which was small in number and had only a very limited financial backing. The population of the mountains put up with the restrictions imposed by the law, while parliamentary candidates turned the situation to their account, and succeeded in obtaining continual evasions of the law in order to win the favours of the electorate. This led to the detriment of the forests and threatened the integrity of the mountain lands.

In addition, the safeguards provided by the law did not touch the chestnut zone, and it is in this particular zone, which in central Italy reaches the high elevation of more than 1,000 metres, that the most recent geological formations (eocene, miocene, and pliocene) are found, and these are the formations most subject to erosion and landslides. Technically incomplete, disliked by the mountain population on economic and social grounds, the law of 1877, although it succeeded in preventing further deforestation, was unable to aid in the improvement of the economy of the Italian mountain districts.

The shortcomings of this law were soon felt, and we had in consequence a series of new acts which sought to complete and improve it, as, for example, the Act of 1888 concerning reforestation. The Italian Congress of Forestry held in Bologna in 1909 marked, however, the beginning of a new forestry system which was developed in the law passed by Luigi Luzzatti in 1910.

This law not only established a state forest service autonomous and of an industrial character, but it provided as well important state encouragement for the reforestation and amelioration of the mountains by formulating the principle that there does not exist in Italy a forestry problem in itself, but a more complicated problem of the mountain areas which is to be solved by united effort.

Of the new Italian policy, the most important exponent was Arrigo Serpieri who became the head of a rapidly increasing and important group of scholars and politicians. Under the influence of this school there were passed in 1915 the law of Raineri for the improvement of mountain pastures and in 1912 the law for instruction in forestry. The latter law suppressed the old Institute of Vallombrosa, and formed the Royal Institute of National Forestry in Florence, the direction of which was given to Serpieri. But by that time we were on the eve of the Great War, which marked a pause in the work which had only just begun, and which led to a new and important destruction of Italian forests as a result of the actual fighting and of the turbulence of the post-war period.

Benito Mussolini with his historic march on Rome in October 1922 saved Italy from the abyss into which she was about to fall, and one of his first works as Prime Minister was to summon as his collaborator Arrigo Serpieri, who at once dedicated himself to the reorganization of the Italian forest legislation. In consequence, the Fascist Government on 30 December 1923 passed the Italian Forestry Code which marked the beginning of the mighty work which is being carried out to-day under the Fascist régime towards the solution of the problems of Italian forestry.

3. *The Fascist Forest Legislation.* The main principles of the legislation set out in the Forestry Code of 1923 are as follows:

(*a*) To secure and defend the stability of the soil and the regularity of the water supply.

(*b*) To aid the development of a rural economy in the mountain districts by encouraging silviculture and the improvement of mountain fields and pastures.

(*c*) To co-ordinate the whole complex action of the amelioration of the mountain districts with the reclamation of the hills and the plains.

(*a*) For the achievement of the first object two methods are used, one purely juridical and consisting of limitations of the rights of property, the other mostly administrative and composed of direct and indirect, complete or partial intervention of the State.

In the first category is placed the forestry bond which comprises a whole series of regulations which compel the owners of this bond property to look after and cultivate properly their woods and pastures, and forbid them to plough unless suitable works are provided to ensure the stability of the soil and the regularity of the water supply. The bond now is not restricted, as it was by the law of 1877, to areas above the level of the chestnut. It is no longer incomplete and therefore useless. It covers large areas, sometimes complete valleys if necessary.

The second aim has its most complete and radical expression in the direct intervention of the State, which as in other countries, for example in France, demarcates the area of mountain land which is to be reforested and put in order. After demarcation, the State bonds the lands and carries out the necessary works entirely at its own expense. In this connexion the law of 1923 and successive enactments have introduced a new system—the possibility of grants. The State can lend money either to the public 'Enti' (provinces, counties, &c.) or to owners of private properties united in a partnership for the carrying out of the work necessary for the hydroforestal regularization of a mountain basin, while the 'Enti' above mentioned may rely on receiving credits for the rapid development of the works, the amount being paid back later by the State in annual sums spread over a period of some decades. Thus, without putting too great a strain on the finances of the State, it has been possible to give considerable assistance in the work of mountain restoration. Another original feature of Italian legislation in this field is that it permits the control of stream flow in the mountain basins not only by means of reforestation, but also with works of protection and consolidation and the regularization of agricultural lands. These provisions are naturally adapted to the conditions in the Italian mountains where, as we have said, agriculture must be linked with the forests and the pastures.

(*b*) The provisions of the State for aiding the development of rural economy in forest and mountain districts result in the direct safeguarding of the forests and pastures of the nation, and in increasing their wealth.

All the State forests are under the control of an independent authority which makes provision not only for the administration of this wealth, but also for its continued increase. This is done by the purchase of property either forested or bare soil which is capable of subsequent afforestation. As for the forest and grazing properties of the communes and 'Enti Morali', which, as has been stated, were in a poor condition, these are now placed under the care and control of the State. There are two methods employed in the supervision of such properties. In the first, as in Switzerland, the 'Enti' are compelled to provide directly their own technical staff; or secondly, as in France, they may hand over the control to the State authorities. In the first case, however, the State gives large contributions towards the salaries of the directing and supervising staff. In any case it is always the duty of the 'Enti' to observe the plans made for the woods and forests which are under the control of the forest authorities. The law also aids in the protection of these properties by preventing their division among the peasantry for cultivation, because this in the past has been one of the principal causes of the ruin of the mountain regions, especially in meridional Italy.

In addition, the assistance given by the State for silviculture and for the improvement of grazing independently of the ownership of the property is very considerable. For example, an owner who reforests one of his properties in the mountains—as long as it is bonded—is free from taxation for a period lasting from 15 to 40 years, and he receives a premium up to two-thirds of

his expenses. In this way there are contributions for the amelioration of mountain pastures which vary from 20 to 35 per cent. of the expenditure according to the types of work.

(*c*) In a country like Italy where the flow of water is always irregular and is frequently the cause of serious damage on account of this irregularity and of the orographical structure of the soil, the problem of restoration in the mountains is of vital importance not only for the mountains themselves, but also for the soils of the plains and the hills. Any basic improvement or alteration in this last zone is, therefore, connected with the regularization of the mountain basins. On the other hand, this regularization, which requires sometimes a drastic limitation of pasture and cultivation, and even on occasions their suppression, can be aided by removing the excessive strain of the population in the mountains, and creating for it new sources of life in the plains and hills.

The conception of the problem already contained in the Forestry Code of 1923 has been further developed in the law passed in 1924. The Mussolini Law of 28 December 1928, concerning the Bonifica Integrale (Land Reclamation), opened out vast possibilities by the assignment of financial help. Seven milliards of lire, of which 4,300 millions are to be provided by the State, are to be devoted over a period of twenty-four years to increasing the productivity of the soil of Italy. And in this magnificent scheme the mountain problem has the place of honour. It no longer concerns only reforestation and control of rivers, but deals with the integral restoration of the mountains. It includes the improvement of woods and mountain agriculture, the building of houses, stables, dairies, roads, aqueducts, &c. No other solution was possible when faced with the 42 million inhabitants of Fascist Italy, and with the historical necessity of an increase in the demographic power of the nation.

Since 12 September 1929 Benito Mussolini has entrusted the execution of his historic law to a specially appointed Under-Secretary of State, and to this important post he called His Excellency Professor Arrigo Serpieri, Director of the Royal Institute of Agriculture and Forestry at Florence. That is to say, Mussolini relied on the man who about thirty years ago had sown the seeds of the new Italian policy, and who was the author of the Forestry Code of 1923. This appointment was in itself a guarantee that the problem of forestry would receive proper attention in the great work of restoration.

4. *The National Forest Militia.* Every law, however good, is ineffective unless it can be applied. In this respect, one of the most original creations of Fascism is the National Forest Militia. In 1927 the Royal Forestry Corps was dissolved and in its place was created the new Militia which is both a military and a technical body, whose members wear the black shirt and receive military orders from the General Command of the Voluntary Militia for National Security, and technical orders from the Ministry of Agriculture and Forestry. The National Forest Militia contains technical elements who formerly belonged to the Royal Forestry Corps, and this nucleus is reinforced by a younger element carefully selected. To-day, the National Forest Militia is composed as follows:

328 officers and 3,672 under-officers and soldiers to whom may be added about 100 civil officials, a number altogether exiguous when compared with the vast size of the work which the Militia must accomplish. The work which it has to carry out is as follows:

(*a*) Technical work, namely reforestation and regularization of streams; management of State forests and of forests belonging to communes and 'Enti'; preparation of plans for woods and the amelioration of mountain pastures; assistance, advisory work, and propaganda in the field of silviculture; forest industries, pastoral industries, and mountain agriculture.

(*b*) Police services. Vigilance work. Observation of the general conformity to Forest Laws, especially as regards the bonds, and to the game laws.

(*c*) Military and complementary services. Forest mobilization, military police duties, auxiliary services for public security, suppression of smuggling, assistance during public calamities, &c.

To understand the immensity of the work which the National Forest Militia must accomplish, one must remember that while awaiting the compilation of the new lists of forest bonds established by the law of 1923, a law of 1926 said that all woods without exception were to be bonded, which means that the 3,672 officers and men must supervise the entire forest area of Italy, 5,600,000 hectares, mostly in mountainous and difficult districts.

But the Militia makes up for its scarcity in numbers by the spirit of sacrifice, the patriotism, and the courage of its members, and thus the forest wealth of Italy is now safe from repetitions of past destruction and is increasing and improving steadily. All the officers of the Militia undertaking technical work have completed courses at a university, and have degrees in forestry, agriculture, or engineering. Those with degrees in agriculture and engineering have also taken a special course in forestry at the Royal Institute at Florence. In 1933 an ordinance for the training of the personnel of the Militia came into force. The schools are:

(*a*) A School of Military Training for Officers at Florence. In this school officers pass by competition, and they must at the same time attend the forestry section of the Royal Institute in Florence. Once they have obtained their degrees of Doctor of Science and Forestry and have passed the examinations of the school of Military Training the cadets are promoted to the rank of officers and enter into the active service of the Militia.

(*b*) The School for Sub-Officers at Vallombrosa. Here theoretical and practical courses are given annually for the further instruction of men selected for the National Forest Militia. These men after this course obtain the right to promotion to the rank of sub-officers.

(*c*) 'Arnaldo Mussolini' School at Cittaducale (Rieti). Into this school are admitted, after public examination, the youths who are annually drafted into the Militia. They complete here a course of practical and theoretical lectures.

With this organization the National Forest Militia possesses schools, lower, middle, and higher, in which the technical and military preparation of its members are attended to by a carefully selected staff of instructors.

As a result of this training and of the spirit of discipline and devotion to the cause, the Militia has been able in a few years to work out an admirable programme, and has made itself a powerful instrument in the reforestation for which the Fascist Government gave great financial aid.

The following figures show, better than any words, the work undertaken by the National Forest Militia. From 1928 to the end of 1933, in six years, 41,450 hectares have been reforested by the Militia without counting the reafforestation carried out by other people. In addition, 20,000 hectares of poor and degraded forests have been restored. In 1933 alone, the Militia was working on 1,132 areas scattered over 83 provinces, and 10,732 hectares were reforested. In the pre-War period of 1867–1912 the area annually reforested in Italy was about 708 hectares; in 1911–22 it rose to 1,891 hectares, and during the Fascist period of 1922–6 it rose to about 2,000 hectares annually.

Great developments have taken place in the improvement of mountain pastures. It is sufficient to say that in 1933 for these improvements sums of money were granted about 300 times as large as those of the pre-Fascist period.

The State forests have increased notably with new acquisition so that, in place of the 224,000 hectares of 1926, they covered an area of 265,000 hectares in 1933.

Notable progress has been made in the preparation of working plans for the management of State forests, and with important administrative reforms. A marked improvement is also noticeable in the management of forests belonging to the communes and 'Enti Morali'. This is due to the preparation of working plans, and to improved supervision, the services of the forest police becoming increasingly effective. Forest fires are now greatly reduced in number and severity compared with what took place in the past.

As has been seen, everything seems to demonstrate that in this atmosphere created by Fascism of discipline and collaboration between the classes, the guardianship and improvement of the forests under the National Forest Militia is developing with increasing intensity, and the beneficial effects of this service cannot long remain unnoticed. Streams are controlled, denuded hillsides are reforested, numerous roads are being built in the mountains to facilitate communications, pastures are being made more fertile, and are adequately irrigated and given reasonable buildings. A completely new atmosphere pervades the mountains of Italy, which are now definitely being restored. In this work the National Forest Militia is adequately supported by the National Secretariat of the Mountains which helps communes and landowners in the mountains to plan and execute works of restoration and improvement.

5. *Instruction and Experimental Work in Forestry.* The centre of higher instruction in forestry in Italy is in Florence, where the Royal Institute of Forestry and Agriculture and the Royal Silvicultural Experimental Station

FIG. 1. One of the numerous nurseries which the Forest Militia have started to supply plants for reforestation

FIG. 2. Successful afforestation in the high mountain zone. Soil sterile and subject to continuous degradation

Commune of Coli, Piacenza

PLATE III

FIG. 3. Regulation of the Sova torrent. Works carried out in 1931, with dry stone walls

FIG. 4. One of the dams built by the Forest Militia for the control of the Stura torrent in the basin of the river Sieve (Tuscany)

PLATE IV

are situated. In the Institute, which is in effect a University, the course of forestry takes four years to complete, after which a science degree in forestry is taken. As we have said, it is attended by the cadets of the National Forest Militia. During the summer, these students carry out a course of practical work in the forest of Vallombrosa, where the old Institute of Forestry, abolished in 1914, was situated. The Royal Experimental Station for Silviculture attached to the Institute in Florence in 1923 has been made a self-governing Institute of university standard with purely experimental aims. Its work extends over the whole of Italy, and it has, therefore, a national character. Its head-quarters are in Florence, but it also owns a building at Vallombrosa attached to the nursery and experimental forests.

6. *Propaganda.* During the pre-Fascist period, the Touring Club of Italy did a great and noble work of propaganda on behalf of forestry, especially through its great apostle, L. V. Bertarelli. On the advent of Fascism the Club has extended its activities in the field to an even greater extent, and is now giving special support to investigations into autotraction by producer gas in order to increase the value of wood charcoal. The Club also possesses the most important of the Italian Forestry publications, *L'Alpe*, which has been directed by the professors of the Royal Institute at Florence since 1914. But the great step in propaganda was taken by the lamented brother of the Duce, Arnaldo Mussolini. Deeply interested in and attracted by the mountains and the problems of forestry, Arnaldo Mussolini founded the National Committee for Forestry, of which until his death he was president. The object of this Committee was to send out to every citizen, and above all to the Fascist youth, the call for a rebirth of the nation's forests. Since the premature death of Arnaldo Mussolini, to whose work is due among other things the founding of the Forest Militia, the National Committee has been presided over by the Secretary to the Fascist party, and it has head-quarters in Rome with branches in each of the Italian provinces.

Thus, under the inspiring influence of the Duce of the new Italy, the work of the State and the citizens, the work of the National Forest Militia, the extensive studies and experiments marking the scientific progress of silviculture, the propaganda which penetrates more and more deeply into the minds of the people, all combine to make Italy determined to continue decisively the efforts to repair the errors of the past, and to place the forests and the mountains in the great movement of progress which characterizes the Fascist era.

SOCIETY'S AND OTHER NEWS

NOMINATION OF OFFICE-BEARERS AND COUNCILLORS

Members are reminded that nominations for election to office at the Annual General Meeting in 1935 must be in the Secretary's hands by 31 October next. As there is no other opportunity of reminding members, they should act on this notice. There is no special form of nomination, the only requirement being that the nomination must be in writing and be signed by two Professional members (i.e. Fellows or Associates). Nominations are required for the following:

Office-bearers, to hold office for one year: President, Vice-President, Editor of Journal, Business Editor, Secretary and Treasurer, and Auditor.

Councillors, to hold office for two years: three.

A list of those now in office will be found at the beginning of this number. The retiring Office-Bearers and Councillors are all eligible for re-election.

SOCIETY OF FORESTRY IN SUOMI

The Society of Forestry in Suomi (Finland) honoured the Society with an invitation to attend a festive meeting in Helsinki on 18 April last in celebration of the Finnish Society's twenty-fifth anniversary. It was a matter of great regret that in the time available no member could be found able to represent the society at that meeting.

REVIEWS

'Changes in the Cell Contents of Wood (Xylem Parenchyma) and their Relationships to the Respiration of Wood and its Resistance to *Lyctus* Attack and to Fungus Invasion.' By S. E. Wilson, M.Sc., Ph.D., D.I.C. *The Annals of Applied Biology*, vol. xx, No. 4, pp. 661–90, November 1933.

Review by R. C. Fisher

IN this paper Professor Wilson has given an account of the changes occurring in the cell contents of wood after felling and during storage and seasoning which should be of great interest to all concerned with hardwood timbers. The subject is dealt with in two parts: in the first the purely botanical aspect of the changes in the starch content of felled timber is discussed, and in the second the relation between the amount of starch present and liability to attack by *Lyctus* Powder-post beetles or sap-staining fungi and moulds.

Professor Wilson shows, in the first part of his paper, that the history of starch in timber is closely bound up with methods of seasoning. Thus, provided freshly felled wood is not dried quickly, heated to a high temperature, or otherwise treated in a way calculated to kill the cells, these cells will continue to live, and in so doing will gradually use up their food reserves, of which starch is the chief constituent. By sealing the ends of short lengths of oak and ash branch-wood he has been able to delay drying until all the food reserves have been utilized, and the wood has become starch free. The depletion of starch has been shown to progress not uniformly but in the main radially, from the bark inwards. No explanation of this interesting point is offered. A certain amount of moisture must be lost through the bark by such samples, but this loss is not sufficiently rapid to overtake starch depletion.

With these general results available from experiments with timber of small dimensions, observations were made on logs, boards, planks, and timber of commercial sizes, when similar results were obtained. For example, by delayed drying of green logs stored with bark intact and ends sealed, for a time sufficient to enable cell activity to use up all the reserve food material, timber entirely free from starch was obtained. The time required for removal of starch by log seasoning is dependent upon the initial starch content of the timber, according to the species, the time of felling, the width of sapwood, and temperature conditions. In normal practice, however, logs are converted when only partially depleted, in which case it is shown to be impracticable to segregate starch-free from starch-containing timber. In converted timber of large dimensions, 2 inches, 3 inches and upwards in thickness, depletion of the starch content may continue after sawing, but complete disappearance of the starch is unlikely. In discussing the rate of disappearance of starch in a 1¼-inch ash plank cut from a green log when the starch content was high, the results observed by Professor Wilson do not agree with those which might be expected from the records which he quotes from experiments with timber of smaller dimensions. Thus, on pp. 663–4 (figs. 2 and 3), it is stated that in short lengths of ask, oak, and other trees, 2 inches in diameter and ¾ inches in length, after drying at room temperature for six months, the starch had disappeared almost completely from the main mass of the wood, except on the original

surfaces. In the 1¼-inch plants, however, kept under out-of-door conditions, even after 1½ years practically the original amount of starch still remained, despite the delayed drying and the difference in dimensions of the timber. This observation does not appear to be in keeping with the general thesis that rapid drying results in the retention of the starch whilst delayed drying produces starch-free wood.

The effect of immersion of freshly felled timber in running water was investigated, and it is shown that this treatment results in gradual depletion of the starch, whilst the starch content of dried timber, given a similar treatment, remains unchanged.

Among the insects most injurious to the sapwood of hardwoods are the *Lyctus* Powder-post beetles, upon which studies have been carried out in many parts of the world with a view to devising methods of prevention and control. Earlier work on the biology and food requirements of these insects has indicated that they find their food within the cell contents of partly and recently seasoned sapwood, but the true nature of this food material was not determined until Professor Wilson showed, as described in the second part of this paper, the relation between the starch content of wood and its suitability for *Lyctus* attack. By a series of experiments undertaken with the co-operation of the Forest Products Research Laboratory he has shown that starch-free timber is not liable to infestation, and suggests that there exists an immunity starch-level, not yet determined, which should indicate whether timber is liable to attack or will remain uninfested. Whilst most of Professor Wilson's work was carried out with ash and oak, he records some specially interesting observations on the occurrence of starch in willow, a 'fat' tree containing little starch but much fat in winter. It is shown that starch is confined to the outermost—that is, the last formed—annual ring, so that this portion alone of willow timber is liable to *Lyctus* attack. The occurrence of starch in walnut is also discussed, but the relation between its presence and the liability of this timber to *Lyctus* attack is not so clear since, according to Professor Wilson, the heartwood, although immune from infestation, contains starch which, as might be expected, is not affected by a log-seasoning treatment. It is suggested that the heartwood starch is 'distasteful to *Lyctus* larvae, possibly by reason of the presence of other cell contents, and cell-wall impregnations', but the problem calls for further investigation.

In view of the conclusions reached in the first part of his study, Professor Wilson suggests that the best method of preventing *Lyctus* attack is to adopt log-seasoning or water-immersion treatments of susceptible hardwoods in order to produce starch-free sapwood. It is, however, open to question whether log seasoning would prove, in commercial practice, to be economically possible. In this country the method would seem to offer more hope of success than in tropical or sub-tropical climates since there is less danger of serious damage not only to the sapwood, but also to the heartwood by pin-hole borers and other wood-boring insects. The danger of fungal infestation resulting in the decay of the sapwood during log seasoning must also be taken into consideration, especially when it is noted that one of the essential conditions for complete starch depletion is the retention of the bark intact, a condition rarely found in practice. On the other hand, where facilities are available, immersion of logs in water should offer more hope of success.

The separation of immune from liable wood among existing stocks of converted timber by means of an iodine-potassium iodide test is also suggested, but as Professor Wilson points out, lack of information on the immunity starch-level and the impracticability of applying this test to timber cut from partially depleted logs render the method of very doubtful value.

Brief reference is made in the paper to the starch content of wood in relation to fungal attack. Experiments were carried out in co-operation with the Forest Products Research Laboratory, using ash sapwood, and the conclusion was reached that in this timber 'the starch content is a measure of the nutrient value of the wood for common moulds and sap-staining fungi, organisms that feed on the cell contents'.

In summing up this most interesting paper, Professor Wilson draws the general conclusion that the criterion of infestation by *Lyctus* is the occurrence of starch in sufficient quantity to nourish the larvae, and in this he implies the comparative insignificance of other factors, for example, the relation between pore-size and oviposition, moisture content of timber, and the processes which denote ageing. He has demonstrated that in recently seasoned timber starch is necessary as food for *Lyctus* larvae, but it should be emphasized that unless egg-laying can take place the wood cannot become infested by *Lyctus*, despite the presence of abundant starch. The criterion of infestation would, therefore, appear to be, in the first instance, the suitability of the timber for oviposition, as determined by the relation between its pore-size and the diameter of the ovipositor of the insect. Once egg-laying has taken place and the eggs hatched, then the starch content of the wood is of the utmost importance for the successful development of the larvae.

Moreover, the ageing of timber and its relation to the stability of starch may indeed have an important effect upon the duration of susceptibility of wood to *Lyctus* attack, a subject upon which no information is yet available.

Whilst of wide botanical interest, Professor Wilson's paper is of special importance to all concerned with the prevention of insect attack in timber, since it constitutes a valuable addition to the knowledge of the food requirements of an important group of wood-boring beetles.

'Das Lärchenrätsel als Rassenfrage.' By Professor Münch. *Tharandter Forstliches Jahrbuch*, vol. vii, 1933, pp. 437–531.

Review by A. D. Hopkinson

THE subject of races of important species of trees is one that has been given considerably greater attention by foresters during this century than was previously the case. This has doubtless come about owing to the greater use during the later part of last century of artificial regeneration, and the consequent purchase of seed through seed merchants without very great insistence as to its origin.

In this country we have had examples of unfortunate results during the last fifteen years of the propagation of unreliable seed of such species as Douglas fir and Corsican pine, which has given considerable prominence to the subject and demonstrated the importance of origin.

Dr. Münch has made an exhaustive study of the larch woods of Germany and has embodied the results of his work in an article of outstanding importance. This research work was prompted by the unhealthy condition of many of the younger German larch plantations, in contrast to the splendid trees to be found in the relics of the earlier woods and their natural regeneration.

In the course of his investigations Dr. Münch found that, although nearly all the older woods had produced trees of good growth and form and practically free from Larch disease, regardless of soil, climate, and treatment, plantations made during the last eighty years gave very different results. He found that good growth and form or

the reverse, and the presence or absence of Larch disease, could not be correlated to treatment, soil, altitude, or climate. Under the most varying conditions were found both good and bad results, and this caused the investigator to rule out such factors as being the main cause, and to turn his attention to the origin of the seed.

To ascertain the origin of the seed of woods planted in the later part of the eighteenth century was a troublesome undertaking requiring considerable research and not always giving certain results, but the information obtained was of considerable value.

Dr. Münch gives it as his opinion that Silesian Larch is now to be found all over Germany and that the older—eighteenth-century—plantations were mainly derived from Silesian (Sudeten) seed. He has found that trees grown from Silesian seed are practically untouched by Larch disease, whereas trees from Tyrolese seed have not this immunity. Furthermore, the stem form of the Silesian larch compares most favourably with that of Alpine origin, being straighter and more cylindrical; the height growth is better and the branching much lighter. In one case he had an opportunity of observing three generations of Silesian larch which had regenerated twice naturally, and in all three the results were equally good.

Dr. Münch disagrees with Cieslar, whose attitude was that disease was induced by planting in unsuitable localities, and by lack of proper treatment. If Dr. Münch's proposition is correct and applicable to Britain as well as Germany, it is a matter of considerable importance in this country, because there are many districts where the risk of disease is so great that the planting of European larch has been almost entirely abandoned.

The article is well illustrated with thirty-eight photographs, and is well worth studying by all who are interested in the subject of Larch disease.

'Om Variationen hos Tallen (*Pinus silvestris* L.) och dess Samband med Klimatet—Olof Langlet.' *Svenska Skogsvårdsföreningens Tidskrift.* 1934, Häfte I–II, pp. 87–110.

Review by J. Alan B. Macdonald

IN a country such as ours, where afforestation must remain the major concern of foresters—at least for a generation—and where self-sowing is practically unknown, it is not surprising that attention is being directed to an increasing extent towards the question of heredity. To the British forester, therefore, this paper is an important one, and the investigation upon which it is based is a worthy addition to previous work which shows that it is little short of criminal to be indifferent to seed origin.

That the species Scots pine consists of varieties which differ very considerably according to the places from which they come has long been recognized; latterly it has been usual to connect the variation with the climate of native origin. Race trials upon which Wibeck (1920) and Schotte (1923) based this conclusion were, however, concerned mainly with mortality due to frost and disease, the rate of growth, stem form, &c., and they embraced a comparatively small number of races. In 1928 Professor Hesselman instituted a very large-scale investigation into the physiological differences between Scots pine plants of different proveniences. The investigation was of a basic nature, and it was hoped that it would throw light upon the reasons for the changes in characteristics. Langlet's paper discusses the results of the investigation.

It comprised the estimation of content of dry matter, sugar content, &c., in 1-year

seedlings and in the needles of older plants; also, by employing special refrigerators, cold resistance was studied in the laboratory besides in experiments within different climatic regions throughout the country. Part of the seed was used to estimate germination capacity and weight per 1,000 seeds. Methods closely followed those employed by Åkerman (1928) in his famous Wheat race studies.

As a result of the investigation, a connexion was established between the dry matter content, sugar content, &c., and the habitat climate of Scots pine plants; further, it was shown that a correlation exists between dry weight and frost hardiness. Should, therefore, Scots pine plants of various proveniences be collected under controlled conditions, their dry matter during autumn and winter gives an idea of their frost hardiness, and furnishes an indication of the climate to which they are suited. In estimating climate of the various proveniences, length of growing season—taken as the number of days in the year with mean temperature of 6° C. or over—has been employed; the correlation between growing seasons so defined at thirty-seven different places in Sweden and Norway and the dry matter expressed as a percentage of fresh weight of Scots pine plants from these origins is shown to be a very close one by means of a graph. A second graph shows the distinct connexion between the dry matter and the winter hardiness (or mortality) of Scots pine plants—500 of each race from a large number of origins—in three experimental areas at 67° N., 64° N., and 57° N., respectively. At each area the mortality was greatest among plants with low dry matter (i.e. of southern origin), this tendency being specially marked at Gällivare, the farthest north station, and least so at Tonnersjöheden, the most southerly one. As Langlet points out, however, to prove that this variation in weight was continually variable with the change in climate from north to south or from coast to mountains required the examination of a still greater amount of material from an even wider range. Such a comprehensive seed trial was laid down in 1931, when seeds collected in 580 different parts of Sweden were sown, preliminary dry matter estimations being carried out on the seedlings in the autumn. Data are very clearly presented by means of a map, and point to the fact that the dry matter gradually increases from warmer to colder regions; actually the mean dry matter of the south is about 31 per cent. of the green weight compared with 37 per cent. in the extreme north. Scots pine of ninety-seven proveniences were also analysed and results tabulated. The percentage dry matter of material of northern Norwegian provenience is almost 40 per cent.; that of northern Spain is lowest with 27 per cent.; while trees of Scottish origin average 30·1 per cent. With such a mass of data, therefore, the gradual nature of the variation in the dry matter of Scots pine resulting from climatic varieties must be acknowledged, and also the gradual variation of sugar content, cold resistance, rate of growth, and resistance to disease.

It is emphatically stated that the variation of Scots pine is not connected with variation in the number of chromosomes. A constant number is obtained whether the plants originate from north Norway, Spain, Scotland, or Siberia, and the writer has found that with other species also (Douglas fir and *Pinus contorta*) the chromosome number remains the same irrespective of origin.

Much of the remainder of the paper is given over to a discussion of the theoretical hypotheses regarding the gradual nature of the variation. 'One species (also sub-species, variety, form, &c.) is composed of individuals which always have certain inheritance factors in common (incommutable Gene) whilst the remainder (free or commutable Gene) are almost homologous and can be interchanged.' It is admitted that this definition of species is indeed indefinite but possibly 'not more so than the species concept in itself'. It is suggested that the wandering to and fro of Scots pine during the

different ice periods had had something to do with the beginning of variation in characteristics.

'It is to be expected that such variation marks each widely distributed species which exhibit hereditary adaptions to the climate or other continually varying natural conditions. This is the case with Norway spruce', probably also with Douglas fir and *Pinus contorta*. Stress is laid upon the necessity for employing an adequate number of proveniences representing a sufficient number of climatic types in any investigation of the sort. Otherwise we may distinguish only obvious ecological type differences but 'should we choose our proveniences from a sufficient number of districts representing a series of different climatic conditions, then their true nature appears—they are quite simple, single populations out of a series of continually varying populations'.

As to practical conclusions, the writer mentions the importance of being able to determine the position of the isotypes (Wiebeck, 1929) and the danger of employing seed of one isotype outside the lines demarking its limits; probably isotypes follow the trend of the isotherms for the number of days whose mean temperature is over 6° C. Thus the special danger of moving Scots pine from warmer districts, discovered in earlier experience, is confirmed.

The article is in Swedish with a fairly comprehensive German summary. Figures and diagrams are clear and simple.

'Untersuchungen über den Nahrstoffgehalt der Aschen forstlicher Kulturplanzen aus den Halstenbecker Forstbaumschulen.' By E. Manshard. *Tharandter Forstliches Jahrbuch*, 1933, lxxxiv. 2, pp. 105–58.

Review by A. B. Stewart

WITH a view to obtaining information on the manurial requirements of young forest trees experiments were commenced at Halstenbek in Holstein in 1926. In this paper are presented the results of the investigation which has been carried out on the following plants: Norway spruce, Scots pine, Silver fir, beech, oak, Red oak, and ash. Ash analyses have been carried out in 1- and 2-year-old seedlings and also, in the majority of cases, on 3- and 4-year-old transplants of the above species, and the contents of CaO, MgO, P_2O_5, K_2O, and N in the dry matter determined.

The results obtained may be summarized briefly as follows:

1. *Formation of Dry Matter.* In the early stages of growth the deciduous plants develop more rapidly than the conifers. The order of decreasing dry matter contents is: ash, Red oak, oak, beech, pine, spruce, fir.

Relative to the weight of dry matter formed in the first year of growth, there is an extraordinarily rapid increase in the dry matter content of spruce from the first to the fourth year.

2. *Ash Content of Dry Matter.* The conifers have a lower percentage of ash in the dry matter than the deciduous trees have; the order of decreasing ash content is: ash, oak, beech, Red oak, fir, spruce, pine. In both the coniferous and the deciduous plants the percentage of ash in the dry matter decreases as the plant gets older.

3. *Composition of the Ash.* Generally the older the plant the higher is the lime content of the ash; the magnesia content remains about constant. Up to the 4th year there is little or no variation in the phosphoric acid and potash contents of the ash of deciduous plants, but in conifers there is a marked decrease in these constituents. Spruce, with 40 per cent. CaO in its ash, has the highest lime content, whilst pine with 20 per cent. CaO has the lowest lime content of the plants investigated. The potash content is

lowest in the beech and highest in the ash. The phosphoric acid content of the ash of conifers is generally considerably higher than that of deciduous plants.

4. *Composition of the Dry Matter.* For equal weights of dry matter conifers are found to have a lower content of lime and magnesia and a higher content of phosphoric acid and nitrogen than deciduous trees which have been grown under similar conditions. The potash content is more irregular, but is highest in the ash and lowest in the beech.

5. *Nutrient Ratio in the Dry Matter.* In conifers, the mean ratio $P_2O_5 : K_2O$ is fairly constant at 1 : 1·5, but the ratio $P_2O_5 : N$ varies considerably. In the deciduous plants the mean ratio $P_2O_5 : N$ is fairly constant at 1 : 3, but there are considerable variations in the ratio $P_2O_5 : K_2O$. Spruce and beech are found to have similar nutrient ratios, $P_2O_5 : K_2O : N$ being approximately 1 : 1·5 : 3.

6. *Lime Factors.* Except in the pines the ratio CaO : MgO is higher than that normally associated with agricultural plants. The ratio CaO : MgO is approx. 3 : 1 for pine; for the other species examined it varies from 5 : 1 in the ash to 8·3 : 1 in the spruce.

7. *Nutrient Contents of Equal Numbers of the Various Species.* 'Dry Weight' is the dominant factor here and the order followed is that given in 1, above. With increasing age of the plant there is a rapid increase in the nutrient requirement. Attention is drawn to the observation that more nutrients will be required to rear a definite number of pines than will be necessary for the same number of firs. This apparent contradiction to common experience that pines grow on poor soils, whereas firs require better soils, is explained on the basis of differences in the root systems—pines having a much greater root development.

8. *Nutrients removed per Hectare.* The results of the analyses have been used as a basis for calculation of the amounts of the various nutrients removed by the different species from 1 hectare of land, when account is taken of the number of plants per unit area, the composition of the seed, &c. Figures are given in kilogrammes per hectare, and for comparison a similar table is given for agricultural crops.

Numerous references to literature are cited and the results throughout are compared with those obtained by other investigators.

Indian Forest Records, vol. xix, part iii. Silviculture Series. Regeneration and Management of *Sal* (*Shorea robusta* Gaertn. f.). By H. G. Champion, Silviculturist, Forest Research Institute, Dehra Dun. Delhi. Manager of Publications. 1933. Price 8*s.* 3*d.*

Review by Sir Alexander Rodger

ALTHOUGH *Sal* is rarely one of the largest trees in the Indian forests it is one of the most important, and it is said to attain a height of 150 feet, with a clear bole of 60–80 feet and a girth of 20–5 feet, in the most favourable localities, at the foot of the hills in Nepal. Such dimensions, however, are rare and the ordinary *Sal* tree is very much smaller. It grows over large tracts in the United Provinces, Bengal, Bihar and Orissa, the Central Provinces, Assam, and Madras, very often pure or almost pure, and is a very important timber especially for railway sleepers. It likes a well-drained, moist, deep, sandy loam with good sub-soil drainage, and the forests of *Sal* can be divided into the dry and moist types. The former is common in dry, often hilly country, and the latter is found at its extreme in Bengal and Assam where its companions are often evergreen species. The fruits ripen in June and fall at once. A strong wind may carry them more than 100 yards as they are winged. The seed rapidly loses its vitality, and

unless specially cared for will not keep fertile for more than a few days. Twenty-seven days after collection, seed kept loose in a basket had lost all its fertility, but by storing it in lime 45 per cent. was found to germinate. It will thus be readily understood that the problem of obtaining a satisfactory young crop has exercised the minds of forest officers in India for many years. The following quotation from Professor Troup's *Silviculture of Indian Trees* gives a good idea of what frequently happens, even when the seed has germinated well: 'After a good seed year, and with the timely commencement of the monsoon rains, the *Sal* seed germinates readily, and thousands of seedlings are soon found covering the ground. The promise of abundant reproduction, however, is doomed to disappointment, for except under the most favourable conditions, before a year is over the number of seedlings is greatly reduced by wholesale dying-off, though a proportion may survive, the stem dying down and new shoots being sent up the following season.' This death or dying-back appears to be due to several causes. Many seedlings die during the rains, others disappear during the following dry season, and others are killed by frost.

Mr. R. S. Hole, Forest Botanist at the Forest Research Institute, published in 1914 and 1916 the results of his exhaustive experiments on the cause of mortality among *Sal* seedlings. He concluded that an injurious soil factor, which operates during the rainy season, and drought, was largely responsible for the heavy mortality. It was found to be very important that the seedling should develop a strong root during the first rainy season. He recommended aeration of the soil by digging it up, and his experiments further emphasized, among other important points, the value of removing the overhead canopy, while retaining side shade to protect the seedlings from frost and to keep the soil moist during the dry season.

Mr. Champion, on the suggestion of Mr. Shebbeare, Conservator of Forests, Bengal, undertook a comprehensive survey of the work that has been done in the six provinces mentioned above in the elucidation of the problem of the regeneration and subsequent management of *Sal* forests. He was accompanied by a party of officers who had had long experience of *Sal* in the various provinces, and this record contains the result of this tour which was undertaken at the beginning of 1933. The general classification of the types of *Sal* forest adopted is:

A. Dry *Sal.*
B. Moist *Sal.*
C. Coastal *Sal.*
D. Wet *Sal.*

with a number of subdivisions.

'The best treatment, above all with regard to regeneration operations of the different types of *Sal* forest, is very intimately related to their status and stability as sub-climaxes or true climaxes.' Clements' *Plant Succession* of course explains these terms.

Plantations of *Sal*, made earlier than 1910, are very rare, but about 1910–16 very successful methods of artificial regeneration were developed in Bengal, as it was realized that natural regeneration would rarely be adequate. The methods of Bengal have been adapted and employed elsewhere and are now successful in many places, continuous strip sowing being universal. It must not, however, be imagined that artificial regeneration is required everywhere, as in Raipur, for example, in the Central Provinces, is the Peninsular type, where natural regeneration has been satisfactory. A detailed account of the forests visited is given, illustrated with excellent photographs.

As the result of the very detailed investigations made, some recommendations for future practice have been drawn up, which may be briefly summarized as follows:

Collection of information regarding climate and soils, time of leaf-fall, flowering, seed-fall, &c.

Adequate study of all existing types of forest, with the preservation of plots of the important types, maintained in their original condition with as little interference as possible.

Intensive study of burning—a most important matter as it may result in obtaining a crop, or in destroying it, according to local conditions.

A complete study of methods of natural and artificial regeneration, and the treatment of these when obtained. Management generally.

Much of the matter in this report will be strange to British foresters and the species has little affinity to any tree in temperate climates, but the remarkable thoroughness and scientific accuracy of the investigation will make the record of the greatest interest to all who are concerned with silviculture.

Forestry for Woodmen. By C. O. Hanson. Clarendon Press, Oxford, 3rd edition, 1934. Price 6*s.* 6*d.*

Review by the Editor

THIS book has been deservedly popular, and has done much to improve forestry practice since it was first published in 1911. Mr. Hanson's experience in this country has been principally in the south of England, and the book has consequently been more appreciated south of the border than in Scotland, where Nisbet's *Forester* is still the standard book. Forestry is essentially local, and it is almost impossible to generalize without making statements which are not applicable to many conditions, but if the book is studied with judgement, it will continue to be valuable for foresters in all parts of the country.

The book is written in a simple, lucid, and concise manner, and it is a pleasure to read it. It is no small feat to deal with the whole range of forestry in 230 pages, and on every page is Mr. Hanson's personality; he never allows his treatment to become an impersonal outline. Two of the best chapters are on the life-history of a tree—particularly well done—and on working plans. It would be easy to criticize many statements on the more silvicultural sections for the reasons stated in the first paragraph of this review, hence these must be seasoned with personal experience. In some instances, recent developments have not been incorporated; for example, soils should have been discussed from the profile point of view, because this approach is undoubtedly going to be fruitful in silviculture. Nevertheless, this book has a character of its own, and every forester, whatever his training may have been, can profit by reading it.

It is well printed and is illustrated by twelve plates, in addition to text-figures, and it is published at the very low price of 6*s.* 6*d.*, which brings it within the reach of those for whom it is primarily intended.

The Care and Repair of Ornamental Trees in Garden, Park, and Street. By A. D. C. Le Sueur. *Country Life* Ltd., London, 1934. Pp. xiv+257; 42 illustrations. Price 10*s.* 6*d.* net.

Review by W. Dallimore

THIS book has been written in order to direct attention to the necessity for paying proper attention to mature trees if they are to be kept in a reasonably good state of health. The work applies to the arboricultural side of tree cultivation rather than to silviculture, for in the latter instance trees are usually cut down before they reach

their full age, but there are cases where arboriculture and silviculture meet, particularly in park and hedgerow timber; therefore the book has a definite value to all who are interested in trees.

The author commences his work by giving a general review of the life-history of a tree in order to indicate how tree wounds heal. He then describes the pruning of large trees, suggesting how branches should and should not be removed, with remarks on appliances and tools, all well illustrated. He then passes on to wounds in trees, cleaning and protecting woods, and when necessary filling cavities, with a full discussion of methods and filling materials. The treatment of backward trees receives attention as do fungus diseases and pests. Under the preservation of very old trees various methods of supporting heavy limbs are described. Remarks are also given on transplanting large trees, trees and the law, the planting and care of street trees, road planting, and various other items. In the care and repair of old trees it is necessary in the first instance to decide whether a tree is worth the often rather heavy expenditure on pruning, cleaning and filling cavities, and bracing branches, or whether, in some instances, it may not be wiser to remove the old tree and plant a new one. The author very rightly stresses this point.

The numerous illustrations add very materially to the value of the book for they are well chosen and in each instance verify points made by the author. The publishers have done their work well, for good bold type and good paper have been used.

The Experimental Production and the Diagnosis of Frost Injury on Forest Trees. By W. R. Day and T. R. Peace. Oxford Forestry Memoirs, No. 16, 1934. Price 6*s*.

Review by the Editor.

FROST damage to trees and means of reducing it are of first silvicultural importance in this country, and particularly in the south and east regions. Our type of climate, whose keynote is uncertainty in temperature as in other factors, combined with our present silvicultural practice of the use of non-indigenous trees planted in blocks without the shelter of an overwood makes the problem more acute here than elsewhere. Mr. Day is doing a service to British forestry by accumulating data which when complete will provide a foundation on which to improve practice.

The present memoir presents the results of experimental freezing of plants of a number of species in a refrigerator which could give controlled temperatures down to 8° F. The plants were generally 3- to 4-year-old transplants, potted up, and when in the refrigerator the roots were protected by being buried in sawdust. The experiments were confined to the periods September to November, and January to June, and extended over three seasons. The exposure to the different temperatures lasted 6 hours. The relative humidity in the refrigerator was 75 per cent., on the average; after exposure the plants were thawed out at 50° to 55° F. in still, humid, conditions. No claim is made that these conditions are similar to those in nature, and stress is laid on the comparison between the effect on different species, and on the diagnostic characters of frost damage to tissues, with the view to estimating its importance in connexion with the various fungous diseases associated with it. It is unfortunate that the origin of the seed from which the plants were raised was not known in every case, because recent research has indicated that this is relevant.

Douglas fir and Sitka spruce were the species most susceptible to autumn damage. Douglas fir and Scots pine were most affected by winter frost. European and Japanese larches, Douglas fir, and *Thuja plicata* were the most susceptible to early spring frost;

and Douglas fir and *Thuja plicata*, followed by Sitka spruce and early-flushing Norway spruce, then by the larches, to mid-spring frost. Oak, which at the beginning of this period is one of the hardiest species, is, by the end of it, one of the most susceptible, while beech and late-flushing Norway spruce are amongst the hardiest, owing to their lateness. In late spring there is little difference between the species.

It is to be hoped that Day and Peace will go on to study the factors which affect recovery from frost damage. This is of practical importance, and it is probable that here air humidity, soil moisture, fluctuations in temperature, and perhaps soil fertility, and even particular ions will be found to be important.

The memoir is illustrated by ten plates showing damage to the different species.

NOTICES

The Indian Forester, vol. lx, No. 1, 1934.

THE sixtieth anniversary number of the *Indian Forester* contains a number of special articles and messages to mark the notable occasion. The *Indian Forester* has not only a long, but an honourable record, reflecting as it does the history of British forestry administration in India. At times, its pages have been the battle-field of acute silvicultural controversy when each number was eagerly awaited for, and at other times it has wilted in interest. To-day it maintains its best traditions, and its editorials on different subjects are both interesting and informative.

'Tree Roots and the Field Layer.' By A. S. Watt and G. K. Fraser. *Journal of Ecology*, vol. xxi, No. 2, 1933, pp. 404–14.

FRICKE and others have shown that on certain soils the restrictive influence on the field layer or certain constituents of the field layer is removed by cutting the tree roots. The authors started an experiment to test Fricke's conclusions in the Heath Pinewoods of Aberdeenshire: to discover which (if any) plant nutrient or nutrients is limiting to the field layer: to find out in which soil layers competition between tree roots and the roots of the field layer takes place or is most severe: to test the validity of the concept that trees and the field layer are edaphically complementary, and generally to discover the relation between trees and the ground vegetation.

The experiments could not be carried through to completion, but certain interesting results emerged. Previous investigators had not tested their conclusions that water was a limiting factor to the field layer by adding water without cutting the tree roots. Watt and Fraser found that the addition of distilled water did not affect *Deschampsia*, a deep-rooting, or *Oxalis*, a shallow-rooting species. Deep trenching affected both these species beneficially. The results with nitrogenous manures were not conclusive, but it was concluded that increased availability of nitrogen in trenched plots was one factor responsible for the increase in *Deschampsia*. It is considered that the relationship between trees in the woodland and the accompanying herbs and grasses requires to be examined afresh.

'The Use of Aerial Photographs in Forest Surveying.' By G. S. Andrews and L. G. Trorey. *The Forestry Chronicle*, December 1933.

THIS paper records the experience gained in the aerial surveying of forest lands in British Columbia, where 530,000 acres have been mapped during the past two years. The article deals principally with methods.

ADDRESS TO THE SOCIETY[1]

BY W. DALLIMORE

IT has been a great honour to have officiated as your President between two such eminent men in the forestry world as Sir Ralph S. Pearson and Sir Alexander Rodger, both of whom have won fame and high official recognition for services rendered at home and abroad.

I cannot claim such profound knowledge of forestry and its inherent interests as those gentlemen, in fact a suggestion was made to me not very long ago that I could not possibly know anything about forestry owing to my long connexion with the Royal Botanic Gardens, Kew. As there may be some excuse for such thoughts by people who only look upon the gardens as a glorified public park, it may not be out of place in this address to direct attention to some of the activities of the establishment that are little known to the general public, more particularly as the Society has honoured Kew by a visit.

Primarily, the establishment is a botanical institution, but because very large numbers of plants have to be grown, Kew has become as well known as a horticultural as a botanical centre. These general activities are widely understood, but there are others that are little known to the general public. The ramifications of the establishment are world-wide, and it is actually a centre for the collation of botanical, horticultural, agricultural, and silvicultural knowledge. There is a very considerable official and general correspondence with the various parts of the Empire and with many foreign countries. Official reports and other departmental documents are regularly received from the Dominions and Colonies, and a vast amount of foreign literature is digested. Information gained by correspondence and an examination of publications is augmented in other ways, and members of the staff must be ready at any time to disseminate such information, and to examine, discuss, and report upon questions received, as well as to answer the varied questions of visitors.

An establishment involving so many interests must be staffed by individuals possessing varied attainments, amongst which the ability to exercise common sense takes high rank.

The Gardens are under the financial control of the Ministry of Agriculture and Fisheries, and the buildings are owned and kept in repair by H.M. Office of Works.

For convenience of management, they are divided into three principal departments, the whole being controlled by the Director, Sir A. W. Hill, and all administrative questions are settled from his office. It goes without saying that the Director of such an establishment must be an accomplished and versatile man.

[1] Delivered at the Seventh Annual Meeting of the Society, held at Kew on 24 May 1934.

The departments are the herbarium and library, the museums and picture gallery, and the gardens. Each one is controlled by a departmental head who is directly responsible to the Director for the conduct of his charge. The herbarium and library includes a vast collection of dried specimens of plants from all parts of the world, and a very rich and extensive collection of books and drawings of botanical and allied subjects. The department is staffed by botanists who deal with general botany, but particularly with systematic botany, questions of nomenclature, and the preparation of floras of various countries. Individual members of the staff specialize upon definite sections of botanical science, and there is also a botanical artist for the preparation of drawings connected with the various works upon which the staff is engaged.

The museums staff is chiefly concerned with economic botany, and the museums contain a very large and varied collection of plant products, such as oils, resins, rubbers, timbers, fibres, tans, dyes, food-stuffs, beverages, drugs, &c. It is necessary that the staff should possess a wide general knowledge rather than a limited but more profound understanding upon a few sectional subjects. They must know something of the cultural requirements of many kinds of crops grown in temperate, subtropical, and tropical countries, have a good idea of their preparation for market, centres for marketing the mature crop, commercial houses interested in particular home imports, and be able to procure trade opinions and prices upon trial importations of a product from a new source. At the same time they must be good geographers, possess a working knowledge of general botany, and be able to discuss sympathetically the difficulties encountered by producers, importers, and manufacturers. In the department is included a herbarium of dried specimens of trees and shrubs grown in the gardens, and questions relating to general forestry as well as to timber and minor forest products are dealt with. Anatomical work connected with the museum is conducted in the Jodrell Laboratory.

The gardens department includes all the work connected with living plants and the upkeep of the place, the employment of labour, and general business. It is divided into five sub-departments, each one in charge of an Assistant Curator who is responsible to the Curator for the work of the men and the safety and cultivation of the plants under his charge. Some idea of the cultural skill demanded may be imagined from the fact that upwards of 25,000 different kinds of plants collected from all parts of the world have to be grown on 288 acres of land on the outskirts of London, where the atmospheric conditions for several months of the year are decidedly bad. The more difficult work in the gardens is carried out by some 50 Student-Gardeners. They are engaged for 2 years, between the ages of 21 and 25, after serving for at least 4 years at practical horticulture elsewhere. While at Kew they lead a very busy life. They average an 8-hour working day throughout the year at practical work, and they must attend numerous courses of lectures on very varied subjects provided for them mostly in their own time. During the summer each man is entitled to 2 hours weekly demonstrational instruction amongst the living plants. The object in view throughout the course of training is not to turn

out men with high academical accomplishments, but men with a sound general knowledge of horticulture, backed up by a wide general insight of various scientific and other matters bearing upon their work. The application of sound common sense in their work and conduct is encouraged. In fact, they are taught to be self-reliant men, and are given to understand that when they leave Kew they will probably be called upon to accept considerable responsibility, and that any lapse on their part will not only be to their discredit but to the discredit of Kew. I may add that although a small percentage of men who pass through Kew fail to make good, a very large number have won credit for themselves and the establishment not only at home but in practically all corners of the earth, and the maintenance of the fair name of the Gardens is always a strong urge amongst all right-minded men. Minor work is carried out by labourers recruited from ex-service men, and the staff in uniform are drawn from the same source.

It would be difficult to convey an adequate idea of the part played by Kew in silviculture. No conspicuous position is taken in such work by the establishment, but behind the scenes a good deal is accomplished. Officially or semi-officially Kew is in touch with many organizations concerned with forestry and its attendant occupations, and the Director carries out a good deal of Committee work for silvicultural and allied interests. Many a suggestion emanates from the establishment in response to invitations from other bodies. Reports, bulletins, and other publications have to be studied and appraised, sometimes before publication, and many problems set by home and overseas correspondents have to be solved. They are not confined solely to trees grown under silvicultural conditions but to trees in general and to trees of many countries. Questions that crop up are many and varied. Some of them would not appeal to a man who spends his whole time on research, and some might be considered of little consequence for they may be of a trivial nature, but there are others of considerable importance that require very mature consideration before a suitable answer can be given. Whatever the question, important or trivial, it is dealt with as thoroughly as possible and without undue delay. That is one of the unwritten laws of the institution. It is realized that a question that appears trivial may be of importance to the inquirer, and as the place is maintained from the public purse the taxpayer has every right to attention, providing the regulations governing the conduct of the establishment are observed.

In order that contact may be made with all that is going on in agriculture, forestry, &c., the museums have a well-equipped library, and once a week all current serial literature is collected from the general library, looked through, and any article or note that is likely to be of future use is card indexed. An assistant is responsible for this work and if he sees an article that he thinks of sufficient interest to be read by other members of the staff, he marks the place and passes the periodical to the proper person.

Passing from Kew to questions of general silvicultural interest, a retrograde movement in the interests of Empire Forestry has occurred since our last general meeting in the cessation of the work of the Empire Marketing Board.

Amongst the many activities of that body advertising Empire timbers took a prominent place, and funds were provided for a great deal of technical work in the testing of Empire timbers for many purposes for which foreign wood had previously been used. However, an arrangement has been made whereby Empire timbers may still be tested at Princes Risborough, and an official organization is in course of formation that will advise on Empire timber questions in much the same way as the Empire Timber Committee which ended its activities with the closing down of the Empire Marketing Board. Apart from this, good work has been done for Empire Forestry by the Colonial Office sending a member of the Princes Risborough staff upon a second tour to examine, report upon, and assist in organizing the forest resources of Nigeria. It is understood that tours of a similar nature in other colonies are contemplated. The appointment of utilization officers to the Forest Departments in several colonies appears to be a step in the right direction. If they can only find a profitable use for inferior quality timbers, and those woods that are little known, they will accomplish most useful work; the well-known high quality timbers will give little trouble. In fact, inquiries after good quality Empire timbers appear to be on the increase.

It is highly appreciated by all foresters that H.R.H. the Prince of Wales presided yesterday at the Annual Meeting of the Empire Forestry Association.

The change of Directors at the Forest Products Research Laboratory interests home and colonial foresters alike, and I am sure that every member of this Society was very pleased when the honours of Knighthood and Doctor of Laws were conferred upon the late Director. Although the institution is still an infant in years it has made phenomenal growth and its many activities are highly appreciated on every hand, for foresters, manufacturers, architects, and others, all benefit by one or another of the many phases of research conducted by the establishment. Possibilities are being explored of making the work of the establishment more easily accessible by the creation of a branch in Scotland. I am sure that we all wish long life and happiness in retirement to Sir Ralph and Lady Pearson, and every success to Mr. W. A. Robertson, the new Director, in his important work. I am equally sure that in extending good wishes to these two Directors, you would not wish to omit the first Director, Sir David Prain, who had the difficult task of organizing the undertaking in its earliest years, commencing in a single room and carrying on in temporary quarters, before the fine laboratories and workshops at Princes Risborough came into existence.

Rather than comment upon any special work that has been undertaken in connexion with National Forestry during the past year I should like to take the opportunity of passing a few general remarks on it since the end of the War.

To a looker-on with some knowledge of the difficulties that have had to be faced and overcome by those who have had the responsibility of creating a National Forest Service, the work accomplished since the end of the War is deserving of all praise. The difficulties in establishing such an undertaking must have been enormous, and the future must have been fraught with

anxiety. The problem of undertaking the reafforestation of extensive deforested areas, and procuring suitable but more or less derelict land, or land unsuitable for agriculture, for the establishment of new forests, at a period when the whole country was disorganized, and often in face of considerable opposition, was a formidable task, more particularly as those in authority could draw upon little in the past for their guidance. Until very recent years most of the forestry in the British Isles was in the hands of private individuals, each one doing as he thought best, and the largest forests were small in comparison to those that had to be formed. Moreover, there was a dearth of thoroughly trained foresters. A good deal of the advanced forest training in the past had followed continental principles, and there was nothing to indicate that a system suitable for mid-Europe would be equally suitable for the British Isles. Moreover, even for minor work, comparatively few experienced men were available. All forests had to be formed by direct planting which necessitated the import of immense quantities of seed, which could not always be from the most desirable sources, and the rearing of vast numbers of plants. All this prevented those in authority getting on with their work as fast as they might have liked. They had to feel their way, train men, and gain experience over a number of years. Then, as soon as the machinery appeared to be getting into working order, national economy demanded a curtailment of the work and considerable disorganization followed. Soon after the readjustment of schemes other curtailments became necessary in the interests of national economy. Thus, those in authority have been faced with adverse conditions throughout the whole period of their official existence. As all foresters know, the curtailment and rearrangement of plans in forest work leads to very serious complications and loss, but with all these setbacks the establishment of national forests has steadily progressed, and the foundation laid for what we all hope will be a great national asset. From the criticisms one sometimes hears, or sees in newspapers, there are people who apparently cannot understand the very great difficulties under which those in authority have laboured.

Criticisms are sometimes made about the kinds of softwood trees planted in national forests. Taking a long view, I think that, providing good quality timber is produced of any commercial species, it will find a reasonably good market, but if rough, poor quality wood is grown of the most carefully selected species it will have little chance against imported timber except it be in times of national emergency. Pruning while trees are young appears to be absolutely necessary if good quality timber is to be grown, and certain softwoods must not be allowed to develop too rapidly, otherwise the quality of the timber will suffer. The Forest Products Research Laboratory has done very good work in the latter case by its examination of home-grown Douglas fir and Scots pine.

The expense of transporting timber from the forest to the seat of manufacture appears to be one of the most serious burdens forestry and timber merchants have to face, and it is a question that must continue to engage their most careful attention.

One would like to see more attention given to the production of good quality hedgerow timber and small shelter woods or spinneys, particularly in ash and oak country. The advantage of the extended planting and proper cultivation of poplars in damp places on farm land also appears worthy of attention; in fact, farm forestry generally should be encouraged.

Both the Scottish and English Forestry Societies considered the question of examinations for working foresters during the year, and in each case the examination was stiffened up. I do not think the recruitment system for working foresters is all that can be desired. The position of forester should be good enough to attract the best type of country-bred lad from secondary or central schools, and they should be encouraged to enter as forest apprentices. At present, the best type of boy from such schools is attracted to universities or to work away from the land, and youths of very mixed ability enter forests in a casual way and eventually present themselves for a period of training in the forest schools. I would like to see suitable boys properly trained in the forest from the start, with a mixture of practical and theoretical work. I would like to see those who showed ability for specializing given the chance to specialize in some particular way, in fact every one with ability should have a reasonable opportunity of advancement to the higher posts. It always appears to me that every young forest officer appointed to serve in this country would be much better equipped for his work if two years of his early training could be spent at the practical work of the forest. After all, a very great deal depends upon the men trained in the forest as to whether forestry undertakings are to be a success or not. A forest officer can only issue general orders; his subordinates have to carry the work through, but a forest officer should be thoroughly conversant with the difficulties attending the foresters' duties, difficulties that are sometimes not very well understood. Unfortunately, the two very different systems of training for forest officers and foresters at present in vogue, do not always conduce to perfect harmony between the two branches.

The British Standards Association have prepared a list of names for soft-woods which they suggest should be followed by architects and other users of timber. The names selected were mostly in accordance with those given in the list published in the Empire Forestry Association Handbook. The difficulties met with in trying to follow the Rules and Regulations governing Botanical Nomenclature have already been explained at this meeting, and it is hoped that a united effort will be made by the various forestry societies in the British Isles to present a case for definite stabilization of names of common trees, for the consideration of the next International Botanical Congress in 1935.

The death of three prominent foresters has been announced during the last few months: Lord Novar and Colonel Petre—the latter during his term of office as President of the Royal English Forestry Society—and Sir L. Forestier Walker, M.P., for ten years a Forestry Commissioner. Colonel Petre took a lively interest in the new sectional co-operation scheme for the better market-

ing of timber that is at present in course of development amongst owners of woodlands.

I should like to pay tribute to the value of the services rendered by our Honorary Secretary and Treasurer, Mr. R. Angus Galloway, and by our Editor, Dr. Steven. Both work very hard for the well-being of our Society; in fact, we could not get on very well without them. I should also like to thank Mr. Stewart for the work he has done during the past year in getting new members for the Society.

MYCORRHIZA IN RELATION TO FORESTRY. I

RESEARCHES ON THE GENUS *PINUS*, WITH AN ACCOUNT OF EXPERIMENTAL WORK IN A SELECTED AREA

BY M. C. RAYNER

Synopsis.

I. INTRODUCTORY
II. EXPERIMENTAL RESEARCHES ON THE GENUS *PINUS*
III. DISCUSSION OF RESULTS
IV. SUMMARY

I. INTRODUCTORY.

THE field for research offered by the mycorrhizal habit in trees differs in certain respects from that provided by other groups of mycorrhiza-formers. On the one hand, the hosts constitute a large and heterogeneous group of species covering a wide range of systematic affinities with a corresponding diversity of evolutionary history. On the other hand, woodland and forest trees form a single ecological unit in respect to certain edaphic factors of their environment, although subject to widely different climatic conditions of temperature and humidity affecting profoundly the manner in which the organic soil constituents composing these factors undergo chemical change, and the rate at which such changes occur.

Presumably, therefore, the remarkable prevalence of a particular type of structure in the fungus-roots of trees is related with peculiarities of the environment, rather than with anatomical or physiological characters common to the various hosts.

Ectotrophic mycorrhiza, as recognized and named by Frank, affects the sub-lateral root system, and modifies the development and appearance of the rootlets so profoundly that Frank distinguished them as organs *sui generis*. It involves an external investment of the tip and growing region with a sheath or mantle of interwoven hyphae, and the penetration of the cortical tissues by an intercellular system of hyphae forming the so-called Hartig net. When mature, the mantle becomes pseudoparenchymatous, the surface as seen in section being relatively smooth or furnished with hyphae that penetrate the soil about the roots. In mature mycorrhizas, there is usually more or less complete disintegration of the external layer of cortical cells that become merged in the mantle, below which the peripheral cells form a conspicuous 'tannin layer'. The intercellular net varies in extent with the age and structure of individual mycorrhizas and is often coextensive with the cortical tissues.

Structurally, the ectotrophic type of structure contrasts sharply with the endotrophic in which infection is mainly intracellular, leaving the external appearance of the root unaltered (Rayner, 1927). Endotrophic structure of

a type resembling that in many herbaceous perennials is also found in some broad-leaved trees, e.g. poplar, and in some conifers, e.g. *Dacrydium*, *Sciadopitys*, and others. Sometimes it affects the long roots, and is found associated with the usual types of ectotrophic structure.

It has commonly been assumed that a check to growth in length of the rootlet follows the envelopment of the tip and growing region by mycelium. Melin concluded at one time that infection is a direct cause of the limited growth of mycorrhizas as compared with long roots of pine and other trees, and noted that the difference is less when infection is excluded. More recently, Hatch has observed in pine that the rootlets that normally become mycorrhizas are of limited growth whether infected or not, and has expressed the opinion that the effect of the enveloping sheath of mycelium has been over-estimated (Hatch and Doak, 1933). A stimulus to branching does appear to be directly related with infection, and this often takes place so freely as to produce coralloid clusters of short thick rootlets (mycorrhizas) varying in colour with that of the associated mycelium. In the genus *Pinus* and in some others, branching is dichotomous, the 'tuber' type of mycorrhiza being formed when this is condensed and profuse, the individual mantles becoming merged in a general investment of interwoven hyphae. It is probable that 'tuber' mycorrhiza—Melin's 'knollenmykorrhiza'—represents a structural response to local environmental conditions rather than to the activities of special symbionts.

In general, the ectotrophic mycorrhizas of pine and other conifers are annual structures functioning for a single growing season and then perishing. Masui has described a case of renewed growth in mycorrhizas of *Abies firma*, Sieb. & Zucc., but this behaviour is probably exceptional in conifers (Masui, 1926).

There is a rhythmic periodicity in root and shoot growth in seedlings and young trees of pine, and the development of mycorrhizas is related with surprising delicacy to the growth activities of the host and the condition of the rooting medium. This phenomenon is of special significance in connexion with the time of sowing of experimental cultures to test mycorrhizal behaviour (p. 108).

Modern experimental researches have been practically limited to trees of temperate climates. The present paper is concerned with observations on coniferous species, the experimental results relating mainly to the genus *Pinus*, although it is believed that the conclusions reached will prove to have wider application, especially in so far as they have relation with practical forestry.

In Sweden the mycorrhizas of Scots pine (*P. silvestris* L.) have been studied experimentally by Melin, whose work has provided an indispensable basis for further research, and a stimulating example to his successors (Melin, 1923, 1925 *a*). Melin has contributed a preliminary list of common woodland Hymenomycetes proved experimentally to be mycorrhiza-formers for this species of pine and for other conifers: *Boletus badius*, *B. granulatus*, *B. luteus*, *B. variegatus* are proved mycorrhiza-formers for Scots pine in Sweden, and the list probably may be extended to include *Amanita muscaria*, *Cortinarius muscosis*, *Lactarius deliciosus*, *Russula fragilis*, and *Boletus bovinus*. Melin like-

wise isolated certain fungi, proving their association with Scots pine and other species, the identification of which by means of sporophores has not yet been accomplished. The vegetative mycelia of these were named provisionally, *Mycelium radicis silvestris* α, *M. r. s.* β., *M. r. s.* γ., and *M. r. s.* δ, a particularly interesting phase of the work being concerned with the identification of certain mycelia included under *M. r. s.* α with the species of *Boletus* named above.

A number of proved mycorrhiza-formers have also been placed on record for spruce (*Picea Abies* Karst.), Mountain pine (*P. montana*[1] Mill.), and larch (*Larix decidua* Mill.), and some are known for White pine (*P. Strobus* L.), and assumed with great probability for Corsican pine (*P. Laricio* Poir.) and Maritime pine (*P. Pinaster* Ait.).

Sufficient data derived from pure cultures are already in existence to show that there is overlapping of the fungus species associated in the different pines, a fact evidenced in a general way by the facility with which exotic pines form mycorrhizas in Great Britain and elsewhere, and by the prevalence of sporophores of proved mycorrhiza-formers under stands of different species. It may probably be assumed that a large proportion of the root-fungi of any one species of pine are also associates of a number of other species. Assuming that proximity to mycelium of appropriate fungi is a formal condition for healthy growth, this fact should facilitate forestry operations involving acclimatization of exotic species of *Pinus*.

Certain complicating factors exist, however, and must now be considered. Melin's observations and experiments lead irresistibly to the conclusion that different fungi or groups of fungi are associated with Scots pine in different localities and on different types of soil in Sweden. My own observations in Great Britain and elsewhere confirm this. There is, moreover, the phenomenon of 'virulence', a term used by Melin to describe the unspecified physiological state of the mycelium that controls its ability to achieve balanced associations with the roots.

If it be assumed that 'virulence'—meaning the physiological condition of the hyphae in respect to root infection—is bound up directly with the character of the soil, more particularly in respect to certain organic constituents, these somewhat complicated facts fall into line with a number of others bearing on the relation between fungi and hosts in tree mycorrhizas, thus permitting the formulation of a general hypothesis. On this, equilibrium between invader and host does not depend merely on the proximity of hyphae of specific fungi, but requires the presence of physiological variants of these attuned to local edaphic conditions. This theory of 'virulence' satisfies the observed facts, and affords an intelligible explanation of certain very puzzling features in the mycorrhizal reactions of pines and other trees, multiple in character and thus involving the co-operation of fungi belonging to distinct genera, and yet highly specialized since their formation and stability appear to depend on the maintenance of soil conditions very imperfectly understood.

A review, however brief, of the subject of tree mycorrhiza must recognize

[1] In the case of Mountain pine and Corsican pine the older names are used.

the controversial atmosphere that has surrounded it since Frank first described the fungus-roots of trees in the early eighties of last century. For the general botanist, controversy has obscured, not the facts of occurrence, distribution, and structure concerning which there is general agreement, but the evidence bearing on the physiological character of the relation between fungus and host, the nature of the metabolic exchange, if such occurs, and the existence or otherwise of a reciprocal mutualism directly affecting the nutrition of the host trees. Frank, Stahl, and many of their students believed that fungus-roots played a vitally important part in tree nutrition in respect to the utilization of organic compounds of carbon and nitrogen, and to the intake of water and inorganic salts; contemporary plant pathologists like Hartig saw in them only more or less successful defiance to parasitic attack by soil fungi. Nearly fifty years later McDougall, discussing the mycorrhizas of certain coniferous trees, writes as follows: 'It was formerly believed that the ectotrophic mycorrhizal fungi were of considerable benefit to the host plants in that they aided them in absorbing materials from the soil, and this idea is retained in many, even of the latest, botanical text-books. There is no evidence in favour of such a hypothesis, however, and it is the consensus of opinion among recent workers on these structures that the fungi are merely parasitic on the roots of the higher plants and that the higher plants receive no benefit at all from the association' (W. B. McDougall, 1922). Referring to the fungus-roots of a number of coniferous and other species from the central Rocky Mountain region, he further concluded 'that the ectotrophic fungi studied are in all cases parasitic on the roots of the host plants, and that the trees are in no way benefited but may be harmed by the mycorrhizal relations . . . the ectotrophic mycorrhizas here studied should be classed under antagonistic nutritive conjunctive symbiosis, which is ordinary parasitism' (W. B. McDougall, 1927). The late Professor Masui distinguished between obligate and facultative mycorrhiza-formers of trees. For the former, he found 'no evidence that the roots are benefited by the association with such fungi'; but considers that the latter, among which he classes the Boleti, 'supply a certain amount of phosphorus and other salts to the host roots' (Masui, 1927). The conclusions of both these observers are based on field observations, supplemented in those of Masui by chemical and microchemical tests.

In striking contrast to these views, Melin considers that mycorrhizas possess a vital significance on raw humus soils, thus summarizing his more important conclusions:

'Ich habe zu zeigen versucht, dass die Mykorrhizen für die Pflänzchen und Bäume auf Rohhumusböden und verwandten Bodentypen eine vitale Bedeutung besitzen. Sie müssen demnach bei der Waldpflege soviel als möglich begünstigt werden. Welche Wege hierbei einzuschlagen sind, wird sich erst nach weiteren eingehenden Untersuchungen detailliert angeben lassen. Theoretisch hat man danach zu streben, dass die Wurzeln mit den zweckmässigsten Pilzsymbionten in Verbindung kommen, dass diese eine genügend hohe Virulenz besitzen und über zweckmässige Stickstoffverbindungen verfügen.

'Ausserdem ist es wahrscheinlich, dass künftige Untersuchungen zeigen werden, dass einige Mykorrhizapilze bessere Stickstoffvermittler sind, als andere. Ist dies der Fall, so müssen die besten Pilze auf Kosten der anderen begünstigt werden. Wie dies zu erzielen ist, lässt sich natürlich jetzt nicht sagen. Die Organismen des Bodens zu beherrschen, dürfte zu den schwersten Problemen der Bodenbiologie gehören.

'Mit der Konstituierung der Symbiose mit den nützlichsten Pilzen ist aber die Aufgabe der Waldpflege hinsichtlich der Mykorrhizen noch nicht zu Ende, vielmehr handelt es sich jetzt darum, dass der Stickstoffbedarf des höheren Symbionten gedeckt werden kann. Da eine künstliche Zufuhr von Nährstoffen in den meisten Fällen nicht in Betracht kommen kann, handelt es sich darum, zu versuchen, die Humusdecke in einem zur mykotrophen Nahrungsaufnahme geeigneten Zustande zu erhalten. Wenn sich auch hierfür noch keinerlei bestimmte Richtlinien angeben lassen, so dürfte man doch sagen können, dass der lockere Rohhumustypus (vgl. oben) der für die Pilze günstigste ist, und dass Waldpflegemethoden, die den Stickstoffumsatz in der Rohhumusdecke fördern (vgl. Hesselman, 1917 *b*), auch die Mykorrhizapilze und damit die Stickstoffassimilation des höheren Symbionten begünstigen' (Melin, 1925 *b*, p. 119).

Since their publication, these opinions have been reinforced on the practical side by comparative observations on mycorrhiza-formation by pine seedlings in different kinds of raw humus in Sweden (Hesselman and Melin, 1927); and also by the studies of Lindquist on the soil conditions favouring reproduction of spruce (Lindquist, 1932).

It is not contended that Melin's pure culture experiments to demonstrate that conifer seedlings with mycorrhizas can utilize organic compounds of nitrogen more efficiently than those without mycorrhizas, can be accepted as conclusive evidence on the matter, although with the improved methods of culture now available it is likely that the published evidence could be strongly reinforced. Melin's conclusions, however, are based not only on these experiments, but on his very extensive comparative observations on conifers and other trees in Scandinavia, on the reaction of many of their proved mycorrhiza-formers in pure culture to changes in the substrate, on the behaviour of seedlings of Scots pine and other conifers with and without infection, and on observations and experiments demonstrating the production of normal fungus roots under pure culture conditions. Many of these observations are still unpublished, and the literature quoted must be regarded as only a first instalment of Melin's contribution to the subject of tree mycorrhiza.

It is noteworthy that the conclusions of most of the modern workers holding a contrary opinion depend mainly on observational data not reinforced by experiment. Indeterminate conclusions have been expressed in two recent papers. In one, 'The Relation of Mycorrhizas to Conifer Roots', describing field observations and laboratory experiments on a number of coniferous species, McArdle states that 'no conclusive proof was obtained that the presence of mycorrhizae on the roots of seedlings is either helpful or harmful to the seedlings' (McArdle, 1932). In the other, an account of his studies on tree roots, Laing concludes that the relations of mycorrhiza with the nutrition of conifers is 'an open question' (Laing, 1932). Both these papers have been reviewed recently by the writer (Rayner, 1934).

Attention must now be directed to certain mycorrhizal phenomena, the imperfect recognition of which is believed to 'be responsible for much needless controversy respecting the physiological relations between fungus and host in trees' (Rayner, 1934).

Frank believed that the ectotrophic type of structure was sharply distinguished from the endotrophic by absence of intracellular infection. So far as the genus *Pinus* is concerned, this view is no longer tenable, and it is now generally accepted that mycorrhizas of ectotrophic type are frequently subject to intracellular infection varying in intensity and in the details of infection, such mycorrhizas being described as *ectendotrophic*.

From Swedish soils, Melin described several structural types of mycorrhizas for Scots pine, among them two kinds of forked mycorrhizas (*Gabelmykorrhiza*), and a tuber mycorrhiza (*Knollenmykorrhiza*). Of the former, one is ectotrophic in structure with very scanty intracellular infection of the outer tannin layer by fine hyphae; the other is similar in general structure, but shows rich intracellular infection of several (usually three) layers of cortical cells. Within these the mycelial complexes undergo digestion as in the root-cells of Orchids; the hyphae disintegrate, and the granular products finally dwindle and disappear. The tuber type of mycorrhiza, known to be due to association with certain species of *Boletus*, was similar in general structure to that last described with heavy infection of a large proportion of the cortical cells followed by intracellular digestion.

Comparative examination of mycorrhizas of seedlings of Scots pine from different nurseries, and of seedlings and older trees from a great variety of soils in Great Britain and elsewhere, combined with study of the fungus-roots formed by experimental seedlings in field plots and pot cultures, have convinced me that ectendotrophic structure shows great variability in respect to the manner and incidence of intracellular infection, and the occurrence or otherwise of hyphal digestion by the cells of the cortex. Observed inconsistencies of structure fall into two classes. In one the mantle and Hartig net development appear to be quite normal, but there is occasional casual infection of the cortex by isolated hyphae similar to those forming the mantle. It is not easy to ascertain the exact origin of these, but they are believed to be branches from the inner surface of the mantle that behave independently of those forming the Hartig net. Into the other class fall the by no means infrequent cases in which cells of the cortex are invaded and often filled by haustorial-like hyphae that have forced their way into the cells from the network of mycelium that envelops them. In sections, this condition may affect a few cells only or practically all of the cortical tissue[1] (Pl. XII, fig. 4). The subsequent fate of these hyphal complexes in respect to digestion varies. Indeed, one of the most difficult problems that faces the modern student of tree mycorrhiza is to define with precision the boundary between

[1] Melin has described intracellular infection of the outer tannin layer by fine hyphae which he describes as 'haustorial'. The term is used by him to describe infection by branched finger-like hyphae not unlike those formed by certain parasites.

normal ectendotrophic structure and intracellular infection of a pseudomycorrhizal kind due to upset of the normally balanced relation, or to parasitic attack.

In mycorrhizas formed under optimum conditions it may be assumed that the physiological relations of fungus and host are balanced and relatively stable. Melin has discussed the conditions—among others, the degree of so-called 'virulence' of the associated mycelium—that determine this state of equilibrium, but at the time of his last publication could offer only tentative suggestions as to the responsible soil factors (Melin, 1925 *b*). He emphasized the importance of correct interpretation of structural details in relation to the existence or otherwise of a mutual relation of a balanced kind, and it can hardly be doubted that exchange of metabolates is bound up with intensity of infection and with the fate of intracellular mycelium. My own observations have satisfied me that the interrelation of fungus and host, as indicated by the structural variations just described, are correlated with, and determined by, fluctuating soil factors with a delicacy of adjustment not generally realized. It becomes therefore of great practical importance to diagnose and interpret these structural differences correctly and relate them, if possible, with definite soil factors. These considerations lead inevitably to study of a correlated mycorrhizal phenomenon, namely, the formation of *pseudomycorrhizas*.

In a paper published in 1917 Melin first described mycorrhizas of abnormal type, the structure of which indicated one-sided parasitism on the part of the constituent fungi. He observed that these were prevalent in Sweden on certain types of soil, e.g. on moorlands recently drained. These *pseudomycorrhizas* show aberrant structure in many respects. In pine they are usually simple and unbranched, more slender and of darker colour than true mycorrhizas. If forked, they may resemble the latter superficially and must be identified microscopically. In section, they show marked abnormality in respect to the degree of development of the mantle, usually absent or much thinner than in true mycorrhizas, in the absence of a Hartig net and in certain cytological details, e.g. the size and appearance of the nuclei and the absence of hypertrophy in the cortical cells. Usually, there is more or less extensive intracellular infection without evidence of digestion.

Melin isolated certain soil fungi and definitely established their association with such pseudomycorrhizas. One of these, named by him *Mycelium radicis atrovirens* α, is widely distributed in Swedish soils, and also in those of Great Britain. Another, *M. r. a.* β, is probably rather less common. A sclerotium-forming Ascomycete, provisionally named *Rhizoctonia silvestris* by Melin, was also identified as responsible for the formation of pseudomycorrhizas, and it is possible that a number of other soil fungi can attack conifer rootlets in a similar manner (Melin, 1923). The subject is complicated by the fact that it is now recognized that pseudomycorrhizas are formed not only by direct attack of certain identified or unidentified soil fungi on young rootlets, but also by attack of these or other species on true mycorrhizas, and—still more important—by disturbance of the equilibrium characteristic of the latter by the action

of inimical factors in the substrate leading to one-sided parasitism on the part of the constituent mycelium.

The present state of knowledge in respect to pines may be summarized as follows: Under favourable soil conditions a majority of the absorbing roots of seedlings and young trees becomes mycorrhizas of one or other of the structural types described. These are more or less ephemeral structures produced annually and functioning for a single growing season. In the presence of certain soil factors not at present susceptible of accurate definition, some or all of these mycorrhizas are replaced by pseudomycorrhizas, the structure of which is consistent with one-sided parasitism of a more or less severe type, the effect on growth and vigour of the host being correspondingly marked. Pseudomycorrhizas are formed in several different ways, but their appearance is invariably associated with the presence of soil factors unfavourable to the production of normal mycorrhizas, either because they inhibit growth of the true mycorrhiza-formers or because they induce a physiological state in the mycelium, and (or) in the young rootlets, unfavourable to the establishment of a normal balanced association.

The ease with which pseudomycorrhizas can be recognized depends upon their nature and origin. When formed by the attack of deleterious soil fungi, e.g. *Mycelium radicis atrovirens*, directly on the young emerging rootlet or on a pre-existing mycorrhiza, they are easily identified and can often be recognized by the macroscopic characters alone. When they originate by disturbance of the normal balanced relation between the rootlet and its constituent mycelium—the latter being that of a true mycorrhiza-former—identification calls for examination of the internal structure microscopically, and may demand careful scrutiny of the data thus obtained in relation to the general health and vigour of the hosts, and also comparative study of mycorrhizas accepted as normal in structure. It is in relation to this last type that ectendotrophic structure of normal mycorrhizas possesses special interest.

As pointed out in a previous communication, the presence of haustorial complexes in the cortical cells is not in itself sufficient to identify pseudomycorrhizas, or even to prove an irreversible parasitic tendency, because intracellular infection of this kind appears to be a normal feature of the mycorrhizas of certain trees; for example, Scots pine. 'On the other hand, heavy intracellular infection without subsequent digestion of the mycelium should be viewed with suspicion and subjected to careful scrutiny before it is accepted as a structural feature of mycorrhizas normal for thrifty trees of the species under consideration' (Rayner, 1934).

Nursery seedlings of species of pine often bear young forked mycorrhizas on a relatively long slender 'stalk' of darker colour. In section, the unbranched region usually shows the pseudomycorrhizal characters just described passing into normal structure, i.e. without haustorial infection, or with it followed by intracellular digestion, in the young forking region. The earlier stage is often correlated with temporary check to growth, purpling of the foliage, and other starvation symptoms, emergence from which coincides with the reduction

and ultimate disappearance of the pseudomycorrhizal features. In my own experiments, complete recovery has been induced in severely parasitized seedlings in one growing season by appropriate soil treatments (Pl. XII, fig. 4). Similar phenomena have been observed in the root systems of young transplants in a condition of check, and in mycorrhizas in old woodlands in which growth of the trees has become unsatisfactory. It must be stressed that familiarity with the types of mycorrhizas from as large a range of natural stations as possible is an essential preliminary to any attempt to estimate the significance of pseudomycorrhizal structure in relation with the nutrition and health of the host. Until such time as a definite standard of mycorrhizal behaviour for any given host is available and generally accepted, the justice of the conclusions stated here must remain to some extent a matter of opinion. For diagnostic purposes in any given area, it should be of practical value and scientific interest to accumulate a type collection of preparations for various tree species, illustrating the observed mycorrhizal or pseudomycorrhizal structures associated with different growth responses on different types of soil.

My own observations and researches have convinced me that the long and sustained controversy respecting the physiological relations between fungus and host in trees had its origin in failure to discriminate between mycorrhizas normal to the species and pseudomycorrhizas induced by unfavourable soil conditions, in particular those forms of the latter that result from disturbance of the normal condition of equilibrium. It is hoped that proof of the soundness of this view will be provided by experimental cultures now in progress in which upset of equilibrium by experimental treatment, leading to the appearance of pseudomycorrhizal structure, is associated with definite symptoms of malnutrition and loss of vigour by the tree. It should then be possible to estimate the importance of the latter as a direct causative factor in poor growth and correlate this with the experimental data now offered. An account of the root system with valuable comparative observations on mycorrhizas and pseudomycorrhizas in *Pinus* spp. with photomicrographs illustrating their appearance and structure will be found in a recent paper by Hatch and Doak, to which reference has already been made (Hatch and Doak, 1933). The structure of indubitable pseudomycorrhizas associated with poor growth in certain species of pine in Great Britain is illustrated in the photographs now reproduced (Pl. XII, figs. 1, 2, 4, 5).

II. EXPERIMENTAL RESEARCHES ON THE GENUS *PINUS*.

Certain basic physiological problems of tree mycorrhiza can be satisfactorily explored only by concentrated laboratory research, including the use of pure cultures. Such are, for example, the reaction of the hosts to different nutrients with and without their associated fungi, the interchange of metabolates between fungus and root, and the relation of microscopic structure with physiological behaviour as deduced from microchemical evidence.

In view of the persistent controversy that has so long obscured the importance of the issues for practical foresters, and the quickening of interest in

these issues following upon increased forestry activities since the War, it is of the first importance that the ground should be cleared for such researches by securing conclusive evidence in respect to the following fundamental aspects of the problem:

1. Can it be proved that the presence of mycorrhizas normal for the species is a *causative* factor in the healthy growth of young trees?
2. Following such proof, in cases where unsatisfactory growth is associated with absence of mycorrhizas, or with the appearance of fungus-roots of aberrant structure, is the condition of the trees in such respect due to:
   (i) absence of mycorrhiza-formers appropriate to the species, or
   (ii) the existence of soil conditions inimical to the formation of mycorrhizas of a type beneficial to the trees?

The future of profitable research on tree mycorrhizas is bound up with the answers to these questions.

If the subject is to be removed once and for all from the region of controversy, where it has been so long becalmed, adequate experimental proof must be supplied that the fungus-roots of trees play a role in nutrition as important as that recently reclaimed for it by Melin (Melin, 1925 *b*). Only thus can the results of scientific inquiry be made to appeal to foresters, already bewildered by puzzling features in the establishment of new plantations in various parts of the world and by the conflicting views of botanists.

The present contribution deals with an attempt to provide the necessary evidence to answer these questions and to place the knowledge so gained at the service of forestry.

In the first instance, the scope of the research was limited to the genus *Pinus*. In the initial stages, comparative observations were made on nursery stocks and plantations of various ages and in varying condition of native and exotic species of pine in Great Britain and elsewhere in Europe, in the eastern United States, and in the mountains of California. The data thus accumulated led to a definite point of view indicated in the review already mentioned (Rayner, 1934). Some of the conclusions on which this was based were summarized as follows:

(*a*) 'The conversion of a large proportion of the sub-lateral root system into mycorrhizas is a natural and inevitable habit in the pines studied, and the formation of healthy and functional mycorrhizas is regarded as a formal condition for nutrition and growth under woodland conditions, there being a direct causal relation between healthy mycorrhiza and thrifty growth.

(*b*) 'The normal association of fungus and host in pines is a balanced one, closely correlated with local conditions of soil and often operating within very narrow limits. A number of such associations may be formed according to the range of the species, differing in respect to the identity of the fungus associates and the precise character of the physiological balance. Some of these may be interchangeable in different situations; others are more specialized, and, if disturbed or replaced by others, may cause marked interference with vigour and growth directly correlated with abnormal mycorrhizal behaviour.

(*c*) 'The first step in a study of the mycorrhiza of any conifer is the adoption of a standard of comparison by observations on the external structure of mycorrhizas from as large a range of *natural* stands as possible' (Rayner, 1934, p. 311).

Experimental study of selected species of *Pinus* was then undertaken by combining field plots and pot cultures with intensive laboratory study of the resulting material. The area first selected for field plots was on Wareham Heath, Dorset, where sowings had yielded poor and inconsistent results. The area is an exposed one, 50 feet to 250 feet in elevation. The soil, of very poor quality on Bagshot sands, consists of several inches of heather peat over 12 to 24 inches of bleached sand, with sometimes an overlying layer 6 to 8 inches thick of flinty gravel. Both iron pan and moor pan are locally present with marked effects on the surface drainage. The pH values on the experimental plots and elsewhere where the soil was sampled were about 5·5 as compared with a value of 6·0 in Scots pine woods in the immediate neighbourhood. These heaths are subject to severe drought in summer and to local flooding in autumn and winter. The natural vegetation is very poor in species, consisting mainly of Ling (*Calluna vulgaris*) with Heather (*Erica Tetralix* and *E. cinerea*) locally. On the better parts patches of Bracken are present with Heath Grass (*Deschampsia flexuosa*) and Moor Grass (*Molinia caerulea*); *Juncus* spp. and *Sphagnum* spp. occur in the wetter parts.

Accurate data are not yet available as to the distribution of known mycorrhiza-forming fungi, but *Boletus bovinus* is present, and it is probable that other species of *Boletus* likewise occur.

The original Forestry Commission sowings from 1924 to 1927 were made on unploughed land, and the results on the poorer parts in 1929, when I first visited the area, had been thus described in a forestry report:

Germination of Maritime pine and *P. radiata* D. Don was good, of Corsican pine bad (that of Scots pine subsequently on the very poor and exposed parts selected for experimental purposes was invariably very bad). During the first and second years after sowing many seedlings died outright, the survivors lingering on in a condition of more or less complete arrest 2 or 3 inches high or less; there was no growth, the older needles turned brown, the younger becoming yellowish or reddish green in late summer. During the fourth and fifth years from sowing, a small percentage of the seedlings emerged from check and became green and bushy, and a still smaller percentage reacted similarly during the sixth year. In 1929 there were many blanks and puzzling inconsistencies of behaviour; e.g. a small patch of seedlings suddenly beginning to grow vigorously while those a few feet away remained practically moribund.

There are no standing trees or felled stumps of Scots pine on this part of Wareham Heath, but on similar soil, e.g. at Ringwood where such occur, it was recorded that seedlings grew markedly better over the old rooting area, young trees 2 to 3 feet high contrasting with those 2 or 3 inches high outside. Effects of shelter were discounted by forestry experts, who inquired whether the remarkable growth reaction and distribution could be attributed to mycorrhizal activity from the old root systems. Similar behaviour had come under

my own observation elsewhere and had been specially noticeable in an experimental sowing of Maritime pine in and about a felled plantation of the same species mixed with Scots pine.

The general impression derived from close study of the seedlings at Wareham was one of chronic starvation, especially in respect to nitrogenous constituents. Local conditions, with a soil notably deficient in available forms of inorganic nitrogen, offered an ideal opportunity for testing the hypothesis that the inability to form mycorrhizas and so make good the poverty in inorganic sources of nitrogen was directly related with malnutrition in these seedling pines.

On the eastern limits of Wareham Heath (Morden Heath) there are scattered trees of Scots pine and plantations antedating the acquirement of the land by the Forestry Commission. The soil below these trees has a relatively thick layer of raw humus, the trees are in poor condition, and there is no evidence of natural regeneration from seed. Investigation of the roots at certain seasons has revealed notable abundance of *Mycelium radicis atrovirens* α (see p. 102), with heavy attack on the mycorrhizas—so heavy as to be easily recognizable by lens or even naked-eye examination. For example, in August all mycorrhizas examined had been converted thus to pseudomycorrhizas and the condition of the root system in this respect was judged fully adequate to account for the unsatisfactory state of the trees.

On the western limits of the area (Bloxworth Heath) there are plantations of Scots pine of corresponding age in fair condition. The fungus just mentioned is present here also, but the incidence of pseudomycorrhizas due to its attack is comparatively small and appears late in the autumn when mycorrhizas of the current year are degenerating. Photographs of Scots pine mycorrhizas and pseudomycorrhizas from the two parts of the area concerned are reproduced here (Pl. XII, figs. 1, 2, 3, 4, 5).

The eastern part of the heath is now under afforestation and has been tractor-ploughed. There is evidence of attack of *M. radicis atrovirens* α throughout this area, on which the experimental plots about to be described are situated. It remains to be seen whether the measures adopted to improve growth on these plots will provide adequate protection against damage. It is not yet possible to say whether deep ploughing has been a factor in promoting the spread of this fungus from the western limits, or whether it was initially present in the soil throughout this part of the heath, owing to wetter soil conditions and defective aeration.

There is general agreement that thrifty growth of pine and other conifer seedlings is always accompanied by free development of fungus-roots, and also that poor growth and lack of vigour are associated with defective mycorrhiza-formation. No satisfactory evidence has hitherto been offered that the two phenomena are causally related, and the most conflicting views are still held in respect to this. The primary object of the researches now under consideration was to prove that the presence of mycorrhizas normal for the species is causally related with proper nutrition and healthy growth of young trees.

The experimental method adopted was twofold, involving:

(*a*) the application of humus inoculae known to contain active mycorrhizal material to sowings in field plots in selected parts of the area, and to similar sowings in the grounds of the laboratory;

(*b*) checking of the results thus obtainable by similar applications to pot cultures with a soil known to be favourable to growth and mycorrhiza production, steam sterilized on three successive days.

(*a*) *Humus Inoculation.*

The root systems of many of the seedlings already present in the experimental area were very defective. There was little branching, practically no production of tertiary rootlets, and no sign of active growth. The younger region of the roots showed a tendency to rot away without definite symptoms of fungus attack. Mycorrhizas were almost invariably absent; if a few forked mycorrhizas appeared in the better seedlings their structure was abnormal. Seedlings identical in type were produced in pot cultures using the top 6 inches of soil from Wareham Heath. Humus inoculation of such experimental pot cultures gave promising results, and an experimental area was prepared and sown on an exposed part of the heath.

The experimental plots were 1 yard square, with a space between of 2 yards. Control plots were sown both on a screefed surface and on one forked one spit deep. Control and treated plots were quadruplicated. Humus inoculations of seed-beds of three species of pine, *P. silvestris* L., *P. Laricio*, and *P. Pinaster*, were carried out in the springs of 1930 and 1931. Material to treat those of Scots pine was collected from well-established woods in Sweden (S 5) and from two sources in south-eastern Ireland (S 6 and S 7). For Corsican pine and Maritime pine the requisite material was collected from native stands in the forests of Aïtone and Vizzavona, Corsica. The experimental plots were inoculated before sowing by inserting small quantities of the humus material in a series of shallow holes below the seed drills. After filling in the holes, the seeds were sown in shallow drills as in ordinary nursery practice. The amount of humus used was a loosely filled pint measure distributed evenly in 25 holes throughout the yard square plot. As material for the treatment of Corsican pine and Maritime pine from native stands was not available until the sowings here described were 1 year old and the seedlings in very poor condition, those figured are from corresponding plots in the laboratory grounds treated with material brought direct from Corsican forests in the spring of 1931. Since the forest of Aïtone is not free from snow until the end of April, these sowings were perforce made rather later in the spring than is desirable.

It has been found advisable to use a definite technique for humus inoculation experiments. The material used must contain active mycorrhizas of the species, free from any abnormalities of structure and from contaminations by such pseudomycorrhizal fungi as can be identified.

Failure to observe these precautions and the use of material from an old and, as it proved later, degenerating pine wood, has been observed to result

in the appearance of pseudomycorrhizas due to heavy attack by *Mycelium radicis atrovirens* introduced in the inoculum into an area in which this fungus has not been observed previously.

The immediate result of inoculation in this case was improved growth and mycorrhiza-formation by the seedlings, followed in the second season by a rapid falling off in growth and vigour and the conversion of all mycorrhizas into *atrovirens* pseudomycorrhizas. Humus should be carefully selected for its mycorrhizal content and should be used as soon as possible after collection. If delay is inevitable, it should be protected from drying out and stored under conditions as nearly resembling those in nature as can be secured. Precautions should also be observed at the time of application. It has been found that the best procedure is to make a series of holes about 2 inches deep along the seed drills, place a pinch of humus in each, and fill in quickly. The material should be neither buried deeply nor left so near the surface that it will dry out. Failure to use material *known* to contain mycorrhizas of a desirable kind, or to observe the precautions just mentioned, may lead to inconsistent and puzzling effects, and has probably been responsible for the contradictory results yielded by humus treatments in the hands of foresters. Attention must be given also to the time of inoculation. Mycorrhiza-formation in pines shows a definite periodicity correlated with the rhythmic alternation of root and shoot growth. Under conditions naturally favourable, mycorrhizas are formed by seedlings about July in the first year and late sowing apparently causes postponement of this activity. The most satisfactory results have been obtained from humus treatments at the time of sowing, as now described. Inoculation of pot cultures or seed-beds from pure cultures of mycorrhizal fungi has been done effectively during June and July when favourable weather conditions offered.

It is evident that the improved growth observed depends upon biological causes of a *reciprocal* kind. Both roots and mycelium must be in the appropriate physiological condition. It is believed that this is adjusted with great delicacy to the edaphic environment, especially with those factors that relate to the organic soil constituents. The treatments gave remarkable results, the seedlings contrasting sharply with those from the control plots. They continued to grow steadily without showing symptoms of passing into a condition of check, the needles were green and of normal length, and the root systems well branched with freely developed mycorrhizas *of the same structural types as those observed in the inoculum supplied*. It was noticeable that the beneficial effect of inoculation was general throughout the plot, as would be anticipated if the stimulating effect were due to biological factors rather than to manurial action. Sample seedlings of Scots pine from the two control series and from the treated plots are shown in the photograph now reproduced (Pl. V, figs. 1, 2, 3, 4).

Similar inoculation experiments, using humus from native forests in Corsica, were carried out in 1931 on Corsican pine and Maritime pine in the laboratory grounds in Regent's Park, London. The plots were prepared by removing soil to the depth of 1 foot and replacing with a prepared compost of light loam and sand with a small amount of leaf humus in the form of leaf mould from broad-

leaved trees. Humus inoculation was carried out as described for Scots pine in field plots, but the sowings were later than is judged expedient owing to the difficulty of collecting the necessary humus material in Corsica earlier in the year.

The effects of these treatments were similar to those described for Scots pine, resulting in remarkable stimulus to growth, accompanied by free development of mycorrhizas with mycelium and structure identical with that formed by trees growing in Corsica. The results were alike in both species of pine, and the improved growth during the first season was maintained and intensified during the second spring after sowing. Precautions were taken to keep the seedlings free from smoke deposit and the plants were unusually large and vigorous for conifer seedlings raised and grown in London (Pl. VI, figs. 1, 2).

The evidence provided by these and similar experiments was unexpectedly precise and convincing. It is clear that profuse mycorrhiza-development in the cases described does not result in a drain on vitality due to parasitic attack by the mycelium since the seedlings with mycorrhizas are larger and markedly more vigorous than the controls that formed no mycorrhizas. In the second season, the former started root and shoot activity at least two weeks earlier than did the controls, and showed strikingly stronger growth.

For these remarkable effects on the size and vigour of seedlings of three species of pine there can be only two possible causes. Either they are biological in origin, depending on the activity of micro-organisms contained in the inocula that determine likewise the formation of mycorrhizas by the seedlings, or they depend on active manurial constituents in the very small quantity of humus used. In order to test the latter possibility, experiments were carried out with a rooting medium steamed for forty minutes on three successive days, such partial sterilization destroying effectively any fungus mycelium present.

(*b*) *Humus Inoculation into Sterilized Soil.*

Using selected material from an old stand of Scots pine known to contain active mycorrhizas, the experimental procedure was as follows: the potting material was filled into new pots of which two lots were heated in a steamer for forty minutes on three successive days. The pots were kept for several days before sowing, during which time they were twice watered with autoclaved rain-water in order to reduce the possibility of toxicity due to heating. One series (B) received no further treatment. In another series (A) 10 grammes of the untreated humus was added to each pot. Those of a third series (C) were filled with the untreated humus and treated similarly. All pots were then sown with the same numbers of hand-picked seeds of Scots pine.

The results of this experiment demonstrate conclusively that the observed beneficial effects on growth and vigour depend on biological processes initiated by the small humus inoculum supplied, the latter leading simultaneously to the formation of mycorrhizas exactly similar to those formed by seedlings growing on the same humus untreated (Pl. VII, figs. 1, 2, 3).

The control seedlings from B pots, containing sterilized humus only, formed no mycorrhizas and made less vigorous growth (Pl. VIII, figs. 4, 5). As between

seedlings of the A and C series, there was little or no difference; those of the A series were at one stage slightly more vigorous, doubtless as a result of the partial sterilization, and this slight manurial effect must have affected equally the control seedlings of B series. The root systems were identical in every respect.

The beneficent effects that follow upon the addition of small quantities of the appropriate humus in the right condition to seed-beds are evidently controlled by factors operating within comparatively narrow limits, since they are readily influenced by variation in the experimental treatment, as, for example, the date of sowing. Thus, improvement is well marked in seedlings from sowings up to the end of May, but diminishes or is imperceptible in those from later sowings. In July sowings increased root development has been observed, but mycorrhizas are not usually formed during the first year and improvement in shoot growth may be slight.

It may be inferred, moreover, that the biological causes responsible are reciprocal in origin. Thus, seedlings of Corsican pine and Maritime pine raised in Wareham soil are already in an unthrifty condition at the end of one year's growth, and they have not been observed to benefit from appropriate humus treatment applied in the spring of the second year. Whether they become capable of doing so eventually is a matter of biological interest, but is clearly not one of practical importance. In general, the effects observed vary directly with the technique used. It is therefore important that a suitable technique for promoting mycorrhiza-formation by means of humus treatments should be carefully worked out and standardized. These observations may provide a clue towards explaining the irregular and often confusing results yielded by empirical humus treatments in the hands of foresters.

The way is now clear to explore the alternative explanation of mycorrhiza deficiency offered in an earlier paragraph (p. 105). Is the observed condition in this respect in seedlings showing defective growth and vigour from the area under consideration due to: (*a*) absence of the appropriate fungi, or (*b*) soil conditions inimical to mycorrhiza-formation?

(*a*) *Presence or Absence of Appropriate Fungi.*

Mycorrhiza-forming fungi specific to Scots pine are present in woods and plantations around the experimental plots, and *Boletus bovinus* is believed to occur sporadically throughout the originally sown area. It is perhaps significant that sporophores of this species of *Boletus* are often conspicuous in close proximity to groups of trees that have emerged from check and are growing freely. More evidence with respect to this matter is desirable because members of this genus were among those placed by Melin in the group called by him 'symbiophiles', members of which were believed to require the proximity of an appropriate host for complete development. With this exception, observations on the Hymenomycete flora of the district are still fragmentary, and it would be rash to assume that optimum conditions in respect to suitable mycelium exist throughout the sown area.

The other species of pine under observation are exotics and present a rather different problem, since there is at present no exact information as to the identity of their root fungi under normal conditions.

In Maritime pine, mycorrhizas of a normal type are freely formed under certain conditions on the Dorset heaths although inhibited in seedlings in many parts of the new sowings at Wareham. In Corsican pine, comparative observations in established stands elsewhere in Great Britain show that mycorrhiza-formation may be normal, but suggest that disturbing conditions are not infrequently present. There is now available for the first time a standard of comparison provided by mycorrhizas of this species collected in Corsican forests. It is possible that absence of appropriate fungi or of a suitable grouping of species may be wholly or in part responsible for the observed inconsistencies of behaviour of seedlings of this species of pine. In the newly sown area under consideration mycorrhizas were absent or abortive, and growth of the seedlings very defective. Under certain conditions *P. contorta* can also form mycorrhizas quite freely in the area. In general, it appears certain that many of the mycorrhiza-formers of Scots pine can serve also for Maritime pine, Corsican pine, and *P. contorta*. In view of the existence of healthy, well-grown stands of Corsican pine and other exotic species in this country it is probable that abnormalities in respect to mycorrhiza-formation are of critical importance only in relation to the establishment of new stands by seed or planting in poor and unfavourable soils.

In the case of Scots pine, field plots at Wareham yielded evidence that whereas mycorrhiza-formation and greatly improved growth can be induced experimentally in one growing season by inoculating seed-beds with small quantities of suitable humus, the improved growth is not maintained at the level first observed, either because the mycorrhizas are attacked by deleterious soil fungi and converted into pseudomycorrhizas, or cease to function freely for other reasons. Similar conclusions were reached in respect to Corsican pine and Maritime pine, especially the former species; for *P. contorta* suitable material from a natural stand was not available for experiment, but there can be little doubt that the mycorrhizas formed by this pine are subject to the same general criticism, although this species seems to form natural mycorrhizas more freely in untreated Wareham soil than does Corsican pine.

The conclusion was therefore reached that, while mycelium of one or more fungi capable of forming normal mycorrhiza with all the pines studied was present throughout the area, soil factors inimical to its symbiotic activity and proper functioning were actively responsible for the condition of the original sowings. This conclusion was confirmed by the reaction of the seedling roots in field plots and in pot cultures of the same soil, subjected to treatments designed to relieve this hypothetical soil condition.

(*b*) *Existence of Inimical Soil Conditions.*

In respect to soil factors generally, field observations confirm the results of laboratory experiments and provide independent proof of the extreme sensi-

tiveness of young tree roots to environmental conditions affecting nutrition and also mycorrhiza-development. In the soil now under discussion, absence of mycorrhizas is associated with an unhealthy and often moribund condition of the younger rootlets, many of the morbid characteristics of seedlings in the field being reproduced in pot cultures. Apart from consequences following upon the methods adopted in the original sowings, and also from those associated with the existence of soil toxicity probably mainly due to defective aeration, it is believed that the condition of the unhealthy and semi-moribund plants described is a starvation phenomenon—in large part one of nitrogen starvation. Experiments with inorganic nitrogenous fertilizers confirmed the results obtained by other observers, viz. that it is difficult to make good deficiencies in this way without serious disturbance of the root-shoot growth ratio in certain species of pine (Aldrich-Blake, 1930). It is believed that in soils poor in inorganic nitrogen the nutrient requirements of the young trees are normally met by a proper mycorrhiza development, and this view is confirmed by the observations and experiments described in the present communication.

Demands upon space render it impossible to discuss here the effects produced by various manures upon mycorrhiza-formation in pines. That it may be promoted in certain cases by the addition of manures has been placed on record by Laing (Laing, 1932). The effect of phosphates is of particular interest in this connexion and is now the subject of special research. In the heath soil under consideration, mycorrhiza-formation can be induced by the application of various phosphatic manures, and it is worthy of note that different species of *Pinus* react differently to the same manure in respect to this.

With reference to soil toxicity, there is no doubt that the superficial peaty layer in this soil contains substances actively injurious to root growth. Better aeration following deep ploughing or the conditions of pot culture reduces the toxic effect, but the seedlings still root poorly without mycorrhizas or with a feeble development of mycorrhizas having abnormal structural features.

Attention was focused upon the possibility of ameliorating the unfavourable conditions by methods practicable in forestry practice. The view was reached that the factors inimical to mycorrhiza-formation must be sought in the constitution of the superficial humus layer in respect to certain organic constituents. The working hypothesis adopted assumed accumulation of a peaty layer having a relatively high proportion of cellulosic constituents as compared with proteins and lignins. The assumption that a higher protein and lignin content would render the substrate more acceptable for mycelium of the mycorrhiza-forming fungi naturally present or those introduced by humus inoculation was based partly on recorded observations on the nutrient preferences of the mushroom (Styer, 1928, 1930), partly on the inimical effects observed from the addition of raw cellulose to a favourable soil, and reinforced by notes on the rapid decomposition of woody detritus observed in coppice and woodland soils containing the mycelium of known or suspected mycorrhiza-formers.

Alleviation of the inhibiting conditions thus assumed was sought by the preparation and application of certain organic composts. The raw materials for these are of the nature of waste products, and their preparation consists of a composting treatment calculated to hasten the removal of cellulosic constituents, and provide an organic dressing rich in proteins and nucleic acid compounds and in lignin. A full account of these composts and of the growth reactions induced in seedlings of pine and other conifers, with a discussion of the exact significance believed to attach to them, will be published independently at such time as the results of experiments now under observation become fully available. The effects on the growth of young trees are so remarkable and of so much practical importance that a preliminary account of the experiments is included here.

Compost Experiments.

The organic composts used for the experiments about to be described are derived from raw materials such as straw, sawdust, and in one case hop waste from breweries, composted with small amounts of various organic and inorganic nitrogenous substances. They are described in this paper as C 1, C 2, &c., to C 9, without further reference to their origin or preparation. Their effect on coniferous seedlings has been tested in a series of field seed plots on three species of pine in the Wareham area, and is now under observation in similar plots elsewhere, and in nurseries in various parts of the country; also in a corresponding series of pot cultures grown in the garden of the Department of Botany, Bedford College, University of London.

The pot cultures were grown in a shelter house of the type designed by Möller. This house has proved itself ideal for the purpose required. It provides complete protection from mechanical injury, very considerable protection from soot deposits, with unimpeded circulation of air and a temperature corresponding to—or in very hot weather slightly below—that of the surrounding air. By the use of clean river gravel as a plunging material for the pots, it is possible to maintain a high standard of cleanliness, and to avoid permanent contamination by the micro-organisms involved in experiments, e.g. by mycelium grown out from the bottoms of pots containing active mycorrhizas, since the plunging bed can be sterilized by boiling water or steam, thus providing relatively aseptic conditions for fresh experiments (Möller, 1912). Without such a shelter house it is difficult to grow experimental conifer seedlings satisfactorily in London; by its use I have obtained uniformly good and consistent results so far as the health and vigour of the plants is concerned. With the exception of light attack by thrips during the hot summers of 1933 and 1934, easily dealt with by increasing the humidity, no other pest or disease has been observed at any time.

For pot experiments, new pots and patent drainage shields were used; controls were filled with soil from the experimental area: in the first series the superficial 5 or 6 inches including humus, in the second series the corresponding top soil after tractor ploughing in correspondence with field plot (A)

of the same series. Twelve pots each were used for controls and for each treatment. The proportion of compost used was 25 per cent. of total soil volume.

The field seed plots were each 1 yard square distributed over 1/10 acre, duplicated for treated plots and quadruplicated for control plots. The latter were untreated; each treated plot received a dressing of 10 lb. of compost per square yard, spread and lightly forked in before sowing.

In certain of the experiments, both field plots and pot cultures were run in duplicate series, one treated with compost only, the other with the same amounts of compost after inoculation with known mycorrhiza-formers of the species from pure culture, and, in the case of Corsican pine, also with humus from a Corsican forest.

Inoculations from pure culture were carried out early in July both in pot cultures and in field plots; humus inoculations in the latter were put in at the time of sowing. For pot experiments seeds were hand-picked; in field plots they were sown in shallow drills as in ordinary nursery practice.

The results of these compost experiments can be estimated from the photographs reproduced in the accompanying plates. These illustrate the reaction of Scots pine, Corsican pine, and *Pinus contorta* to two composts with and without inoculation by the mycorrhizal fungi, *Boletus bovinus* and *B. luteus* from pure culture, or by humus from a Corsican forest (Pl. IX, figs. 1–8); the varying results obtained in pot experiments with the same species with seven different composts (Pl. X, figs. 1–6); and the experimental field plots, with sample seedlings from these with and without humus inoculation (Pl. VI, figs. 3, 4; Pl. XI, figs. 1–5).

The cultures illustrated were grown during 1933 and 1934, both years with unusually hot dry summers. Those from field plots had been subjected to almost continuous drought in a very poor light soil from the time of sowing in April 1933 until the sample seedlings were lifted in June 1934. Pot cultures were severely tested by weather from October 1933 until the following spring, a mild autumn encouraging late growth followed by an unusually foggy winter in London. It will be observed that remarkable growth reactions were shown by all the treated plants in varying degree, the effects being extremely regular and uniform in any single treatment. Root growth is greatly stimulated in respect to development and degree of branching of the long roots; sublaterals are freely produced and mycorrhiza-formation is no longer inhibited. It is worthy of note that the hypothesis associating mycorrhiza deficiency in the area with inhibiting effects of the environment rather than with absence of appropriate mycelium receives ample support from the behaviour of the experimental plants in field plots. Both in pot cultures and in the field, the treated plants are more resistant than the controls to bad conditions; they stand the winter better and start growth earlier in the spring. It may be reasonably expected that the improved equipment in respect to absorption provided by increased root and mycorrhiza-development will continue to yield growth increments conforming to the compound interest law.

The following points of interest emerge from close study of the experimental plants:

(*a*) All the coniferous species hitherto treated are sensitive, although the relative degree of effect of each compost varies with the species.

(*b*) The introduction of humus containing specific mycorrhizas, and (or) inoculation with mycorrhiza-formers from pure culture stimulate growth and give increased vigour, although the improvement may be masked by the relatively enormous effects produced by compost treatments (cf. Pl. V, figs. 1–4).

(*c*) There is close correspondence between the proportion of normal mycorrhizas developed and the vigour of seedlings. Structurally, the types of mycorrhizas formed show great variation correlated with changes in the rooting medium produced experimentally, and also with differences in the behaviour of the hosts. Some of the structural peculiarities indicate disturbance of the balance normally existing between mycelium and root cells and are pseudomycorrhizal in character.

(*d*) There is evidence that improved growth, in particular a great impetus to root development resulting in a marked increase in the number of short roots, most of which subsequently become mycorrhizas, precedes any possible effect due to mycorrhizal activity. A similar stimulatory effect on root development follows humus inoculation with material known to contain specific mycorrhiza-formers, and also inoculation into the soil of pot cultures of mycelium of mycorrhizal fungi from pure culture (cf. Pl. IX, figs. 4, 5, 7, 8; Pl. XI, figs. 2, 4). If this stimulation of growth can be correlated directly with the activities of specific mycorrhiza-formers in the substrate *previous to their symbiotic association with the roots*, it opens up a new line of research of great importance in relation to mycorrhizal significance in general, with immediate reference to the physiology of nutrition in young trees and a correct understanding of their nutrient requirements. In general, experimental results obtained from these compost experiments support the hypothesis put forward as a basis for experiment; namely, that inhibition of mycorrhiza-formation in the area under consideration is conditioned by the organic constituents of the soil and can be relieved by treatments that modify its constitution in this respect. It has been learned also that the organic composts that bring about these changes can be used effectively for studying the mycorrhizal activity of coniferous seedlings in response to variation in the root environment. It appears that their reaction in respect to this is one of extreme delicacy, and it is believed that comparative study of the material now available will do much to help towards a clearer understanding of the physiological significance of structurally different mycorrhizas, rendering it possible to discriminate more clearly between those in which the balance is correctly adjusted and various types of pseudomycorrhizas. This matter is of such importance, both as a problem of plant physiology and as one affecting practical forestry, that it is proposed to deal with it more fully in a future publication. The researches already completed point unmistakably to the necessity for *qualitative* as well as *quantitative* estimations of coniferous

mycorrhizas as an index of soil conditions congenial or otherwise to the trees.

That the effects of the organic composts now recorded are *manurial* in the broadest sense cannot be doubted, but it is equally certain that they are not bound up with the amounts of 'available' nitrogen, potash, and phosphoric acid individually contributed. Full chemical analyses are now available for a number of these composts, and it is not without interest to recall that in the initial stages of the work a competent critic reported on one of them—since proved to be among the most effective—on a basis of comparative analysis, as 'an organic manure of comparatively little value'; while another—since proved least successful of all those tested—was approved as a 'first-class organic manure'! That their effect on the growth of coniferous seedlings differs essentially from that of manures containing significant amounts of available nitrogen, potash, and phosphoric acid is proved, not only by their constitution as shown by chemical analysis, but also by the comparative reactions of potted plants other than seedling trees. The behaviour of experimental cultures of tomato, wallflower, tobacco, and sunflower is recorded in the photograph now reproduced and the notes accompanying it. Further comment on these experiments is reserved until they have been tested and extended by further experiment. It may be noted, however, that none of the species used for these pot cultures has been observed to form mycorrhizas under the conditions of the experiment. All are presumably strictly autotrophic in nutrition.

Finally, it must be noted that the composts here placed on record were designed to meet the soil requirements of young pines in a special area. It is not claimed that their use will induce similar growth reactions in any or every type of soil. The extent of their usefulness in this respect can be learned only by extended researches. It is believed, however, that their use and that of others specially designed for local needs and the requirements of other tree species provides the forester with a weapon of great potential value especially in nursery practice. Properly prescribed, experiment has shown they may be profitably employed on the poorest type of soil, and, in a season singularly unfavourable to the growth of trees, they have provided exceptionally healthy vigorous 1-year plants of three species of pine thoroughly well insured in respect to root development. As it is proposed to deal fully with the preparation, constitution, and effects of these composts in a separate communication, it suffices here to offer evidence adequate to justify the provisional conclusions put forward.

III. DISCUSSION OF RESULTS.

When the investigation here described was planned, the first step was judged to be the provision of positive evidence of a direct causal connexion between normal mycorrhiza, development in the root systems of pine seedlings, and thrifty growth of the trees. The experiments described in the present paper establish this with reasonable certainty. No evidence has been found that mycorrhizas of normal ectotrophic or ectendotrophic structure are deleterious

to growth; on the contrary, the introduction of small quantities of suitable material into seed-beds induces formation of mycorrhizas similar to those in the inoculum, and results in marked stimulation of the seedlings involving root and mycorrhiza-development and vegetative growth generally. The crucial experiment of adding a small humus inoculum of active material to a sterilized seed-bed appears to provide conclusive evidence that mycorrhizas resembling those found in a healthy stand of the parent trees exert a beneficial effect upon growth of the seedlings. The amount of unsterilized material introduced is very small—10 grammes or less to a content of roughly 400 grammes of soil per pot; the biological consequences are relatively great, resulting in the formation of mycorrhizas identical with those introduced in the inoculum, throughout the rooting medium.

Attention has been already directed to a phenomenon observed in all successful humus inoculation experiments, whether carried out in field plots or under the fully controlled conditions of pot experiments with sterilized soil; namely, the fact that the subsequent stimulus to growth *precedes* mycorrhiza-formation, is, indeed, directly responsible for it, because it promotes in a very marked degree the production of rootlets destined to become mycorrhizas. The *initial* stimulus cannot therefore be due to improved nutrition depending upon mycorrhizal action in the ordinary sense. To what then is it due? The following outline of a working hypothesis indicates the lines along which further research is proceeding.

Experiment teaches that the character of the substrate plays a critical part in controlling mycorrhiza-formation. For example, when active humus material is inoculated into an unfavourable soil such as that on the Dorset heaths near Wareham, it is believed that the small amount of favourable material introduced with the mycorrhizas has an important effect in promoting growth of the mycelium associated with them. Seedlings in plots so treated continued to grow and now, four years from sowing, provide a striking contrast with controls from untreated beds most of which have perished while the remainder are in a condition of complete check (Pl. V, figs. 1, 2, 3, 4). The general impression derived from continuous observation of these plots is that the great impetus to growth following inoculation is maintained at a lower level when the local effect of the small quantity of favourable humus added with the inoculum is exhausted. The rather scanty evidence available suggests that vegetative activity and 'virulence' in the Melin sense are very closely related with the nature and course of decomposition of the organic soil constituents, thus supporting the conclusions quoted in the first section of this paper (p. 99).

On the Wareham area, this hypothesis has received support from the mycorrhizal response observed when changes in the organic content are brought about by artificial means. It is also supported by the behaviour of such of these fungi as are known in pure culture. The mycelium is extremely sensitive, not only to the hydrogen-ion concentration of the substrate and the presence of certain salts, notably phosphates, but also in respect to the forms of carbohydrate acceptable. The experimental results are satisfied by the hypothesis

that the mycelium of these mycorrhiza-formers vegetates actively in a favourable substrate, liberating nutrients responsible for increased root development, and thus promoting the formation of mycorrhizas which automatically follows. Viewed thus, the latter is the end term of a series of biological activities in the rooting medium, depending at one stage upon the proximity of specific fungi to developing rootlets of the host trees. Intimate association with the rootlets appears to be promoted by a chemotactic effect upon the hyphae, perhaps induced by the liberation of small amounts of organic nutrients in the vicinity of the emerging rootlets; there is no evidence that such directive stimulus is exerted by the tips of the long roots at any stage of growth.

Melin has placed on record the fact that mycelium of the mycorrhiza-formers grows more strongly when in contact with the roots of tree seedlings (Melin, 1923, p. 170), and has also shown that phosphatides exuded by seeds of pine and spruce exert a highly stimulating effect upon the growth of mycorrhizal fungi in pure culture (Melin, 1925, p. 19). Hansteen-Cranner had already made the interesting observation that seeds, roots, and other plant organs exude phosphatides in quantities sufficient for analytical demonstration, and also that roots of the higher plants excrete phosphatides not only in distilled water, but also in nutrient solutions and fertile soils (Hansteen-Cranner, 1922). It remains to be learned how far these facts can be used to explain the stronger attraction apparently exerted on the mycorrhizal fungi by the young rootlets destined to become mycorrhizas.

There is clear evidence that starch disappears from the root tissues of young tree mycorrhizas, a loss probably more than compensated by increased absorption of nutrients following upon mycorrhizal activity. There is likewise ocular and microchemical evidence of movement of metabolates in these mycorrhizas and, in certain structural types, of digestion of mycelial complexes with disappearance of the resulting products. Certain links in this hypothetical chain of events are directly susceptible to experimental test. The fundamental approach by means of pure culture experiments under fully controlled conditions is obstructed by the difficulty of providing a sterilized substrate which will permit growth of mycelium and roots in a natural environment. The provision of conclusive evidence respecting the exchange of metabolates calls for special research with improved technique.

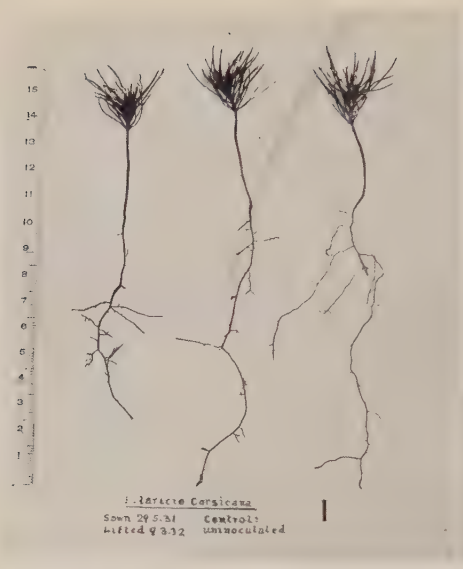
The hypothesis directing the present researches assumes the existence of a delicately balanced system of biological soil activities, bound up directly with the individual peculiarities of the substrate and the presence of certain soil fungi. Conclusive evidence is at present lacking as to the existence or otherwise of a high degree of individual specificity between pine species and their root fungi. Investigation may reveal special cases involving such in host or fungus or in both symbionts. It is believed that the system is most delicately adjusted in respect to the identity of the fungi in relation with the character of the substrate, the complications following upon this being met by the relatively large amount of play offered by the capacity of trees to form multiple associations with a number of fungus species.

Maladjustment or disturbance of any phase of the system upsets the equilibrium characteristic of a stabilized relationship and becomes evident in various ways; for example, by changes in the character of the substrate due to interference with the normal mycorrhizal relations, and by this or other causes leading to the formation of pseudomycorrhizas. The appearance of the latter in any quantity is always associated with deleterious effects upon growth varying in degree with its structural features and the severity of the disturbance favouring its formation. In general, the condition of the root system in respect to mycorrhiza and pseudomycorrhiza development may be regarded as an index of the suitability or otherwise of the soil environment.

The correct diagnosis of pseudomycorrhizal structure requires a working knowledge of the forms associated with any given tree species from as many kinds of soil as possible. Those produced by attack of deleterious soil fungi, e.g. *M. radicis atrovirens* α, are easily recognized; others, perhaps even more important practically as symptomatic of the early stages of disturbance, require further study for accurate definition. In pines, it may be regarded as certain that the following structural features are pseudomycorrhizal in character and indicative of conditions inimical to healthy growth: abnormalities in the structure of the mantle involving marked reduction or increase of width in section, associated with disintegration and absorption of the outer tissues of the root; heavy intracellular infection of the haustorial type *without evidence of subsequent digestion*; relatively heavy intracellular infection of a casual kind, especially when associated with other structural abnormalities. Other suspicious features involve changes in the cell walls, size, nuclei, and contents of the cortical cells of the root, and disappearance of the tannin layer; these require further study for their correct interpretation. The use of the term pseudomycorrhiza for any mycorrhizal development that shows aberrant structural features and is associated with irregularities of growth is convenient for descriptive purposes, but must be regarded only as provisional until a more complete classification of such phenomena is possible.

It is premature to dogmatize about heterotrophic nutrition in trees in relation to the mycorrhizal habit. The Frank hypothesis assumed that compounds of carbon and organic nitrogen became available to the hosts, and this view has been current in the text-books. As restated by Melin, details are still lacking, and experimental verification of the various phases of exchange not yet complete. It is undoubtedly true that failure to form mycorrhizas in soils poor in organic nitrogen is associated with symptoms of nitrogen starvation in young trees, and it has now been proved experimentally that in such a soil this can be quickly relieved by introducing small quantities of humus containing active mycorrhizas of the species. Whether and in what manner the observed improvement in nutrition and growth that follows depends upon direct utilization of organic material brought into circulation by mycelial activity, or upon changes in the organic soil constituents leading ultimately to an increase in the amount of available nitrogen in inorganic form—for example as ammonium salts—requires critical investigation.

PLATE V



P. contoria

P. silvestris

P. silvestris

P. laricio

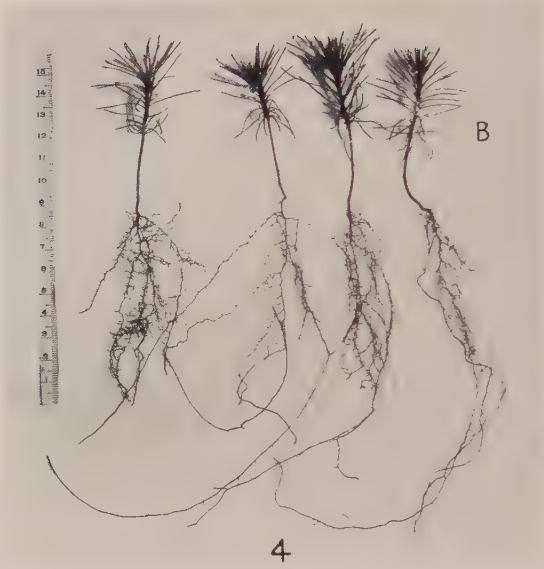
PLATE VI

1

2

3

PLATE VII



4

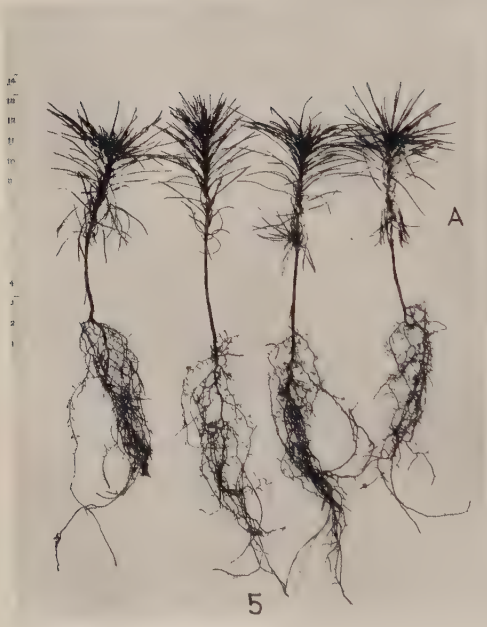


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PLATE VIII

PLATE IX

PLATE X

PLATE XI

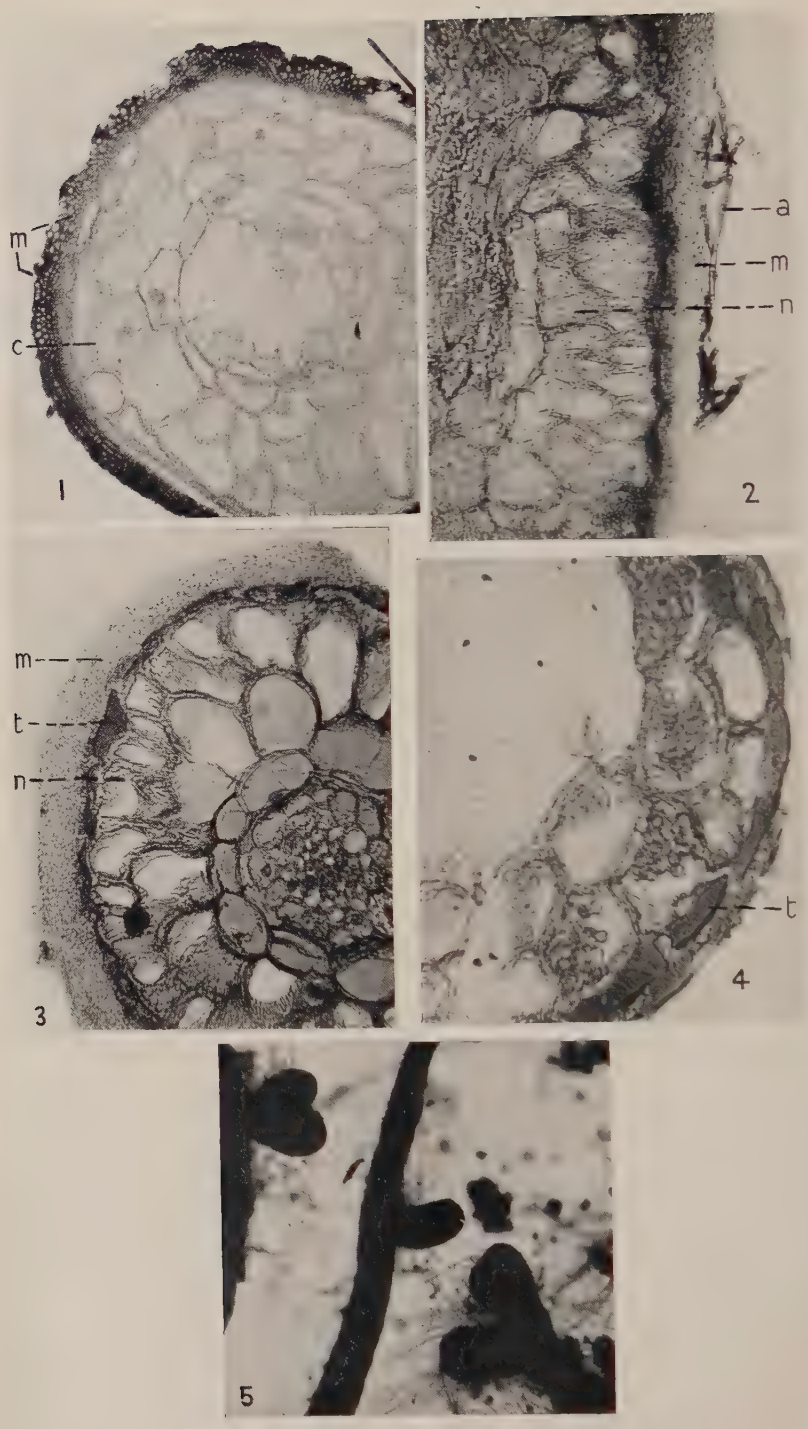
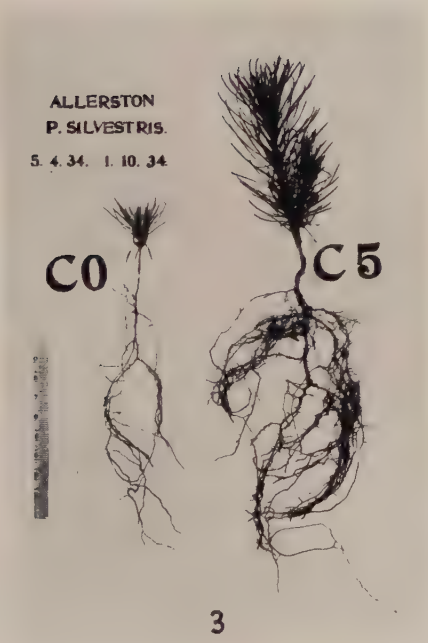


PLATE XII

1

2



3

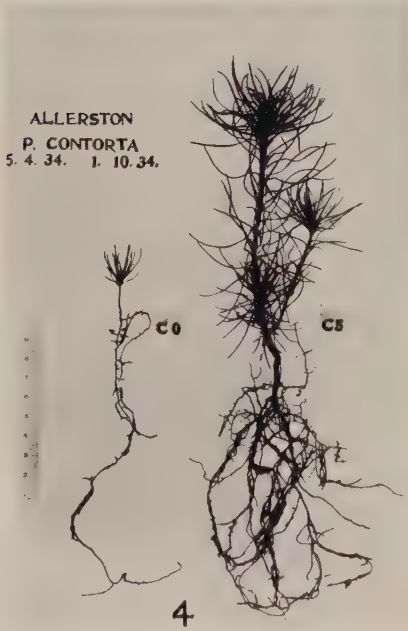


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PLATE XIII

With regard to the origin of the immediate stimulus to growth that follows inoculation with suitable material, it is possible to interpret the reaction provisionally as an indirect effect, depending on the specific action of certain soil fungi (mycorrhiza-formers) in a substrate favourable to their growth. It may prove that some of these fungi—as Melin suggests—require the presence of appropriate hosts to complete their development and produce sporophores.

Experimental analysis of all these problems should help to illuminate certain phases of tree nutrition at present very imperfectly understood. The ignorance still prevailing is evidenced by the irregular responses observed in manuring experiments on young trees. In the present investigation it has been emphasized by the remarkable effects on growth, including mycorrhiza-formation, induced by the use of certain organic composts.

The present paper offers direct experimental proof of a beneficent effect following relief from a condition inhibiting the formation and functioning of mycorrhizas in pines. It likewise provides evidence of deleterious effects, often severe, associated with the replacement of mycorrhizas by pseudomycorrhizas, and the relief of pathological symptoms so induced by artificial changes in the substrate. On the area specially studied, it has been shown that unthrifty growth of pine seedlings is directly related with defective mycorrhiza-formation and that the latter is associated with inimical soil conditions rather than with absence of mycorrhiza-forming fungi suitable for the trees. Remarkable improvement has followed the addition of certain organic composts to the soil.

It is evident that the manurial action of these composts is complex in origin, depending in a remarkable degree upon the character of the soil and the kind of plant growing in it. They were designed to relieve the symptoms induced by a hypothetical condition in a given soil of definite character; the effects produced lend support to the diagnosis. It remains to be learned to what extent the composts can be used profitably on other types of soil (see Pl. XII, figs. 3, 4), and whether first-class seedlings produced by their use in the nursery, well insured as regards root development and mycorrhizal activity, will continue to thrive when transplanted to unfavourable or less favourable soils.

The improvement of soil for afforestation purposes by artificial additions presents obvious difficulties in respect to both technique and cost. The value of the composts described in this paper is at present being tested in nursery practice. Much remains to be learned respecting their action, and the provision of a suitable technique for their effective use must await the results of experiments now under way.

It is hoped to expand the work to include conifers other than pines as well as broad-leaved trees, and extend the experiments to other types of soil refractory to afforestation. The soil experiments described here followed upon independent investigations in this country and elsewhere.

It is impossible to discuss the results obtained without drawing attention to the support they afford for Melin's conclusions, published nearly a decade ago and quoted in this paper (p. 99). They reinforce his view that silvicultural

practice would be well advised to foster the soil conditions favourable to the formation of healthy mycorrhizas in conifers and other trees, to favour soil treatments calculated to promote the activity of mycorrhizal fungi, and to endeavour to take steps to introduce correct strains of such when there is evidence that these are lacking.

IV. SUMMARY.

1. Experimental evidence is offered proving the existence of a direct causal relation between mycorrhiza-development and thrifty growth in seedlings of various species of *Pinus*.

2. In cases where mycorrhiza-development is defective, the condition can be relieved and growth of the trees stimulated by inoculating seed-beds with small amounts of suitable material containing active mycorrhizas of the species.

3. The stimulus to growth that follows such inoculation is initiated by increased production of short lateral roots, and this *precedes* physiological effects depending on the activities of the mycorrhizas into which these roots are subsequently converted. It may be assumed therefore that the introduction of active mycorrhizal material leads directly to the production of growth-promoting substances in the substrate.

4. It is of the first importance to discriminate correctly between fungus-roots with mycorrhizal character indicative of a balanced relation and those of pseudomycorrhizal character indicating parasitism of greater or less degree.

5. The formation of pseudomycorrhizas by pines and probably by other conifers is associated with unfavourable soil conditions. Correct diagnosis is therefore of practical importance as a first step towards the recognition and identification of soil factors inimical to healthy growth.

6. There is evidence of close correlation in respect to particular soil conditions and the behaviour of specific mycorrhiza-formers; disturbance may lead to replacement of mycorrhizas by pseudomycorrhizas with consequences adverse to the health and vigour of the hosts.

7. On certain heath soils in southern England, mycorrhiza deficiency and poor growth were associated features of the pine seedlings present. It has been shown that the former was due to inhibiting soil conditions, rather than to absence of appropriate mycorrhiza-formers.

8. The inhibiting action to mycorrhiza-formation in this area was reversed by the addition of certain organic composts to the seed-beds. Mycorrhizal development followed, accompanied by increases of root and shoot growth which cannot be attributed to the *direct* action on the trees of any manurial constituent added.

In its initial stages the expenses of the work described here were partly defrayed by grants to a Research Committee of the British Association for the Advancement of Science. It is at present assisted by an annual grant from the Forestry Commission of Great Britain, and I take the opportunity now offered to acknowledge this, and also the unfailing courtesy and collaboration of the officers and staff of the Commission. I have to acknowledge also the grant of

a laboratory from the Council and the exceptional facilities afforded by the Department of Botany, of Bedford College, University of London. On its physiological side, the work has greatly profited by the collaboration and help of Prof. W. Neilson Jones. Thanks are also due to Dr. I. Lewisohn for practical assistance in the laboratory.

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EXPLANATION OF PLATES V–XIII

PLATE V. *Pinus silvestris.* Humus inoculation in field plots. Wareham forest, Dorset.

Figs. 1, 2. Seedlings 8 months from sowing. S 1, from untreated control plot; S 5, S 6, S 7, from plots treated with mycorrhizal humus from Sweden (S 5) and eastern Ireland (S 6, S 7); plots dug before sowing. Comparative mean dry weights in grammes of single seedlings of S 1, S 5, S 6, S 7, 8 months from sowing: 0·035, 0·065, 0·077, 0·05.

Figs. 3, 4. Seedlings from same plots 16 months from sowing, identity as in figs. 1, 2. S 2, from control plot as S 1 but plot dug before sowing.

PLATE VI.

Figs. 1, 2. *Pinus Laricio.* Humus inoculation in garden plots. Fig. 1, seedlings from untreated control plot: poor rooting and absence of mycorrhizas; fig. 2, seedlings from plot inoculated before sowing with mycorrhizal humus from Aïtone, Corsica; good rooting with abundant mycorrhizas.

Figs. 3, 4, general view of experimental field plots, Wareham forest, Dorset, showing effects of compost treatments. Note poorness of controls, C 0, and remarkable effect of C 5 on all species. Scale by C 5 plot marked in 6-inch length.

PLATE VII. *Pinus silvestris.* Experiment showing effect of humus inoculation into sterilized soil.

Fig. 1. Seedlings 4 months from sowing: C, native humus untreated; B, same humus steam sterilized; A, as B with addition of 10 gm. of same humus untreated.

Fig. 2. Seedlings of A and B, 6 months from sowing; two pots on left, A; two pots on right, B.

Fig. 3. Three seedlings from each series, 9 months from sowing. Comparative mean dry weights in grammes of single seedlings of A, B, and C, 9 months from sowing: 0·432, 0·320, 0·408.

PLATE VIII. *Pinus silvestris.* Experiment showing effect of humus inoculation into sterilized soil.

Figs. 4, 5, 6. Seedlings as in Pl. VII, fig. 3, displayed to show rooting; note poorer rooting and absence of forked (mycorrhizal) rootlets in B seedlings, and identical condition in respect to root and mycorrhizal development in A and C seedlings.

PLATE IX. Compost treatments of Wareham soil; pot experiments with three species of pine: *P. silvestris*, *P. Laricio*, and *P. contorta* (*murrayana*).

Fig. 1. *P. silvestris*: left to right, Wareham soil; do. + 25 per cent. C 4; do. + 25 per cent. C 1.

Fig. 2. *P. Laricio*: left to right, Wareham soil; do. + 25 per cent. C 4; do. + 25 per cent. C 1.

Fig. 3. *P. Laricio*: right to left, Wareham soil; do. inoculated humus from Aïtone; do. inoculated from pure culture of *Boletus bovinus*.

Fig. 4. *P. silvestris*: left to right, Wareham soil; do. inoculated from pure culture of *B. bovinus*; do. inoculated from pure culture of *B. luteus*.

Fig. 5. *P. Laricio*: left to right, Wareham soil; do. + 25 per cent. C 1; do. + 25 per cent. C 4, all inoculated with humus from Aïtone; cf. with corresponding pots in fig. 3.

Fig. 6. *P. contorta*: left to right, Wareham soil; do. + 25 per cent. C 1; do. + 25 per cent. C 4.

Fig. 7. *P. silvestris*: left to right, Wareham soil + 25 per cent. C 1; do. inoculated from pure culture of *B. bovinus*; do. inoculated from pure culture of *B. luteus*.

Fig. 8. *P. silvestris*: left to right, Wareham soil; do. + 25 per cent. C 4; do. + 25 per cent. C 1, all inoculated from pure culture of *B. luteus*; cf. with corresponding pots in fig. 1.

Seedlings in all pots: 14 months from sowing. The compost C 1 is prepared from straw; C 4 from hardwood sawdust.

PLATE X. Compost treatments of Wareham soil; pot experiments with three species of pine: *P. silvestris*, *P. Laricio*, and *P. contorta* (*murrayana*).

Fig. 1. *P. silvestris*: left to right, Wareham soil; do. + 25 per cent. C 1; do. + 25 per cent. C 5.

Fig. 2. *P. silvestris*: left to right, Wareham soil; do. + 25 per cent. C 7; do. + 25 per cent. C 8.

Fig. 3. *P. Laricio*: left to right, as fig. 1.

Fig. 4. *P. contorta*: left to right, as fig. 2.

Fig. 5. *P. silvestris*: left to right, Wareham soil; do. + 25 per cent. C 2; do. + 25 per cent. C 4; do. + 25 per cent. C 6.

Fig. 6. *P. contorta*: left to right, as figs. 1 and 3.

Composts C 1, C 7, and C 8 are prepared from straw, C 2, C 4, and C 6 from softwood sawdust, and C 5 from hop waste.

PLATE XI. Compost treatments of Wareham soil. Sample seedlings from field plots.

Figs. 1, 2. *P. silvestris*: seedlings from untreated control plots (C 0), from those treated

with compost C 1, and from those treated with compost C 5; fig. 1, composts only; fig. 2, corresponding treatments combined with inoculation of plots with mycorrhizal humus.

Figs. 3, 4. *P. Laricio*: seedlings from untreated control plot (C 0), from those treated with compost C 1, and from those treated with compost C 5; fig. 3, composts only; fig. 4, corresponding treatments combined with inoculation of plots with mycorrhizal humus from native stand, Aïtone, Corsica.

Fig. 5. *P. contorta*: seedlings from control plot (C 0), from those treated with compost C 1, and from those treated with compost C 5. All seedlings were fairly representative of those in their respective plots.

PLATE XII.

Fig. 1. Portion of transverse section of pseudomycorrhiza produced by attack of *Mycelium radicis atrovirens* α on a hymenomycete mycorrhiza, with structure as shown in fig. 3. *m*, pseudotissue of mantle heavily infected and overlaid by mycelium of the attacking fungus; *c*, damaged cortical cells showing original intercellular net. ×200.

Fig. 2. Portion of longitudinal section of young pseudomycorrhiza similar to that in fig. 1, showing early stage of attack on original mantle. *m*, mantle; *a*, mycelium of the attacking fungus; *n*, intercellular net. ×200.

Fig. 3. Portion of transverse section of young hymenomycete mycorrhiza of *P. silvestris*, showing structure previous to attack by *M. r. atrovirens*. *m*, mantle; *t*, tannin cells; *n*, intercellular net in surface view. ×200.

Fig. 4. Portion of transverse section of pseudomycorrhiza of *P. silvestris* presumably due to disturbance of normal relations. Note reduction of mantle and heavy intracellular infection of cortical cells by haustorial ingrowths from the intercellular net. Complete recovery of seedlings showing these symptoms was effected in one growing season by appropriate soil treatments (see p. 104). *t*, tannin cells. ×400.

Fig. 5. Pseudomycorrhiza of *P. silvestris* due to attack of *Mycelium radicis atrovirens* α as shown in fig. 1. Note coarse, dark brown hyphae of the attacking fungus, projecting from surface.

PLATE XIII.

Figs. 1, 2. Tomato plants, 6 weeks from sowing. Fig. 1, grown in ordinary potting soil; fig. 2, grown in similar soil +25 per cent. C 7; cf. Pl. X, figs. 2, 4, showing effect of same compost on pine seedlings.

Figs. 3, 4. Compost treatments of soil at Allerston, Yorks. Sample seedlings from field plots.

Fig. 3. *P. silvestris*: C 0, from control plot untreated; C 5, from plot treated with compost C 5; 6 months from sowing.

Fig. 4. *P. contorta*: C 0, from control plot; C 5, from plot treated with compost C 5; 6 months from sowing. The seedlings shown were fairly representative of those in their respective plots.

PRELIMINARY NOTE ON THE TIMBER OF HOME-GROWN SITKA SPRUCE (*Picea sitchensis* Carr)

BY THE FOREST PRODUCTS RESEARCH LABORATORY

AT the request of His Majesty's Forestry Commission, an investigation is now well advanced at the Forest Products Research Laboratory, Princes Risborough, with the object of forming some estimate of the character of the timber likely to be produced by the plantations of Sitka spruce which have been established in many places on land acquired by the Commission, and on private estates. It was found impracticable to obtain converted timber from the young plantations of the Commission of sufficient diameter for the tests and proposed commercial trials, and so it was necessary to pick trees of sufficient size to yield suitable timber from other sources in various parts of Great Britain.

Five small consignments of home-grown Sitka spruce, drawn from six widely differing localities, were sent to Princes Risborough for test; these consignments being numbered for the purpose of identification 34 (Montgomeryshire), 40 (Kincardine), 58 (Kent), 69 (Norfolk), 142 (Benmore and Glenbranter). In all, timber from 48 logs has been examined, comprising 1,092 cubic feet, and it should here be emphasized that the timber of the first four consignments differed markedly in character from that of the fifth, or last, consignment, which was specially chosen by Mr. J. M. Murray of H.M. Forestry Commission as more nearly comparable in growth to that of imported whitewood or spruce from northern Europe, and of the type which may be expected from the Commission crops in future.

Timber of consignments 34, 40, 58, and 69 contained a high proportion of wide-ringed wood and a fair number of large knots, varying from ½ inch to 2½ inches in diameter, and also numerous pin-knots in the heart zone. Consignment 142, which contained logs from the localities of Benmore and Glenbranter in Argyllshire, Scotland, was much slower grown and consequently narrower ringed, and while knots were rather more numerous than in the other consignments, they were generally of much smaller size.

This last consignment was brought in for test subsequent to the investigations upon the first four, since the conclusion was arrived at that trees from these first consignments were not truly representative of the stands of timber which may ultimately be found in the Forestry Commission areas. Reference to the table on p. 128 will show the localities, soils, and other silvicultural features of the localities from which the trees were obtained.

The logs generally were of fair shape and appearance: reasonably straight, cylindrical, and of even taper, except that in one or two instances they were rather heavily buttressed. Whorls of knots occurred throughout, with a scattering of internodal knots.

The average growth-rate of the trees in each consignment is illustrated diagrammatically in Fig. 1.

Owing to the high growth-rate persisting for the first 40 years or so on most

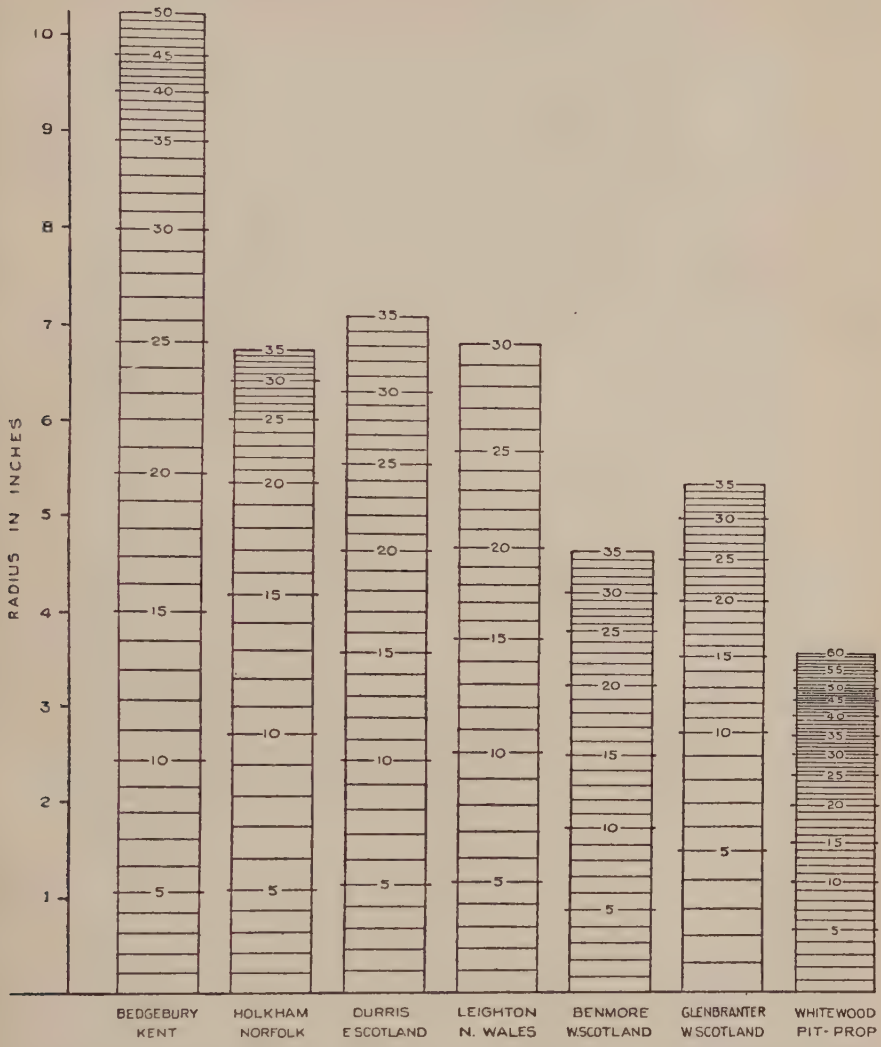

Fig. 1. Diagram showing the average growth-rate of each consignment. The vertical strips show the number of annual rings per inch of radius averaged over 5-year periods. An imported whitewood pit-prop is included for comparison.

sites, the bulk of the timber was wide ringed and of poor quality; while it is not possible to say exactly within what limits growth-rate should be kept it is apparent that material with less than about six rings to the inch is generally very soft and woolly. As may be seen from the diagram the ultimate falling off in growth-rate is fairly rapid, the final rate being as slow as twenty-five

Consignment No.	Number of trees in consignment.	Number of logs in consignment.	Average age of trees.	Average tree height.	Average length bole to crown.	Average length of crown.	Average crown percentage.	Average Q.G. (B.H.).	Average length of logs.	Total volume of consignment.	Soil.	Elevation.	Type of stand.	Spacing.	Stocking.
				ft.	ft.	ft.		in.	ft.			ft.			
34 A	9	9	48	80	39	42	50	12	22	167	Humus over clay	600	From a stand of 16 acres mixed conifers	Spacing about 8×8 ft.	0·9
40 B	11	11	55	90	39	52	57	15	21	281	Humus over gritty loam	250–400	From a stand of mixed conifers	Spacing about 6×7 ft. and 7×11 ft.	1·1 0·9
58 C	7	14	70	101	67	34	33	18	18	410	Sand over loam	300	From a stand of 1½ acres, pure Sitka	Spacing irregular, about 21×21 ft.	0·7
69 D	4	4	52–4	91	58	33	35	15	28	148	Loam over clay	250	From a small stand of pure Sitka in a mixed coniferous wood	Spacing irregular, 18×18 ft.	0·8
142 E	3	3	55	..	..	..	..	8	20	55	Sandy loam over gravel	38	Narrow strip pure Sitka under forest conditions	..	0·7
142 F	3	3	54	..	..	..	..	8	20	55	Fertile reddish brown loam over sand and broken rock	700	Forest pure Sitka	..	1·0
142 G	4	4	49	..	..	..	..	9¾	20	31	Fertile loam over schists	117	Sitka and Douglas in more or less pure groups	..	0·8

Key: A. Leighton Hall, Montgomeryshire.
B. Durris, near Banchory, Kincardine–Aberdeenshire border.
C. Bedgebury, Kent.
D. Fulmodestone Wood, Holkham, Norfolk.
E. Nig Strips, Benmore, Argyll.
F. Cruach Wood, Benmore, Argyll.
G. Glenbranter Forest, Argyll.

rings per inch in some instances; this is unnecessarily slow where the rotation is relatively short, and the proportion of the slower grown timber is too small to affect the quality of the log as a whole.

On conversion, the sawn boards from the first four consignments presented a somewhat rough and unattractive appearance. This was more marked in the case of the faster grown material, in which spiral grain was evident in most logs. Boards from both fast and more slowly grown material were knotty, but, as already mentioned, the wider-ringed material contained fewer knots of a comparatively large size while the slower grown had more numerous but smaller knots. There was no tendency to fly on conversion, and the timber sawed without difficulty.

Purplish stain (identified as an early stage of *Fomes annosus* attack) affected parts of most logs in consignments 34, 40, 58, and 69, but was not observed in consignment 142. The incipient decay indicated by this purplish stain would constitute a serious disadvantage from a commercial point of view, and silvicultural methods to avoid it should receive careful study.

The chief drawback in working this timber is connected with the softness of the springwood zone, and the trouble is naturally more pronounced in wide-ringed timber owing to the greater proportion of springwood present. The soft springwood is liable to become compressed during cutting, and when subsequently released, to rise above the level of the harder summerwood, producing ridging or corrugation. It also tends to crumble in certain machining operations when cut on end grain, and tears up slightly in cutting parallel to the grain.

The cracked dead knots present in the timber of each consignment proved to be troublesome in machining through chipping out and spoiling the cutting edges. But when machined with suitable cutters (frequently honed to a thin edge) the appearance of the sawn stock was greatly improved from the sawn condition, but no really clean first-grade material for better class manufactures was produced.

Material from all consignments was tested by various commercial firms to determine its suitability for different trade purposes. The faster grown material containing large knots was reported to be suitable only for uses such as trench lining, rough boarding, and the rougher qualities of boxes, while the slower grown material with smaller knots was pronounced as fit for the above uses and also the best class of printed wooden boxes. It is important for the latter purpose that a surface good enough to take print should be readily and inexpensively obtainable, and that plugging and filling of knot-holes should be reduced to a minimum. The large knot-holes do not lend themselves readily to this treatment.

There is an indication from laboratory tests and from commercial reports that the Sitka spruce should find a place upon the market, provided that the quality of the timber can be improved silviculturally so that the rate of growth is reduced to not less than six rings per inch, large knots eliminated and stain avoided. How this improvement in quality may be brought about is worthy

of very careful consideration from a forestry standpoint, and also whether or not the species is worth growing upon soils which will also produce good class European spruce (*Picea abies*) or Scots pine (*Pinus silvestris*). But if Sitka spruce is the only species that will thrive upon peat soils at high elevations to produce good marketable timber, it would seem to offer a fair prospect of finding a market upon a lengthy rotation, and of thus becoming in due time a national asset.

It is proposed to publish fuller data in a subsequent communication.

THE MECHANICAL STRENGTH PROPERTIES OF 'BROWN' OAK

BY J. LATHAM AND F. H. ARMSTRONG
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INTRODUCTION.

ON occasion, there is discovered in oak trees grown in Great Britain a deeper coloured reddish-brown wood instead of heartwood of normal colour. The late Professor Groom stated that the feature is confined chiefly to *Quercus Robur*. The coloured wood is known as 'Brown' oak or sometimes as Red oak, the colour and beauty in its varied formation of growth making it a particularly valuable wood for panelling and furniture construction. Besides being present at the butt, the coloration is found in other positions of the stem, such timber being then straighter in the grain and therefore having less figure and usually less colour.

'Brown' oak appears to occur mainly in Great Britain, though it is probably identical with the *pourriture rouge dure* of oak in France: its origin has been ascribed to certain properties in the soil or to incipient decay. These points were examined by Groom, and in the published account of his experiments (1) he showed that 'brown' oak is due to a fungus growth which by its action produces the coloration of the wood. Cartwright, who is re-investigating the problem at the Forest Products Research Laboratory, has isolated from a number of different samples of 'brown' oak a fungus which causes a slow heart rot of oak (2); a full account of this work, dealing with the identification of the fungus and its effect on the wood, will be published shortly.

The presence of a fungus suggests the possibility of a deterioration in mechanical properties. This point, however, has not hitherto been the subject of experimental investigation. In consequence, when samples of 'brown' oak became available for this purpose it was felt that the problem merited attention, and two series of tests have now been undertaken in order to determine the effect of the brown discolouring agent on the mechanical properties of the timber.

MATERIAL.

In the first series the test specimens were cut from a 1-inch board which was irregularly stained with the brown discoloration. The conversion was arranged so that two groups of specimens were obtained, the first of oak of normal appearance and the second of the discoloured wood, termed respectively 'normal' oak and 'brown' oak. As the material was rather limited in quantity, only a small number of test specimens were obtained, and these were allocated exclusively to the static bending test. One-half of the tests were carried out on the timber in the condition as received, namely, about 40 per cent. moisture

content, and the remainder after air-seasoning to about 16 per cent. moisture content.

In the second series the specimens were cut from a butt log in which the discoloration was of a uniform intensity of dark brown throughout the heartwood. In this instance sufficient material was available for the preparation of an adequate number of test specimens. One-half of these tests were made at the moisture content on conversion, namely, 76 per cent., and the other half after air-seasoning to 12 per cent. moisture content.

TESTS.

The mechanical tests carried out were as follows:

(*a*) Static bending tests, from which are obtained the strength and stiffness of the timber under transverse loading applied without shock.

(*b*) Impact bending tests, in which the specimen is subjected to a suddenly applied transverse load, and the property recorded is a measure of its toughness or resistance to shock.

(*c*) Hardness tests, under which is measured the resistance of the timber to indentation by a steel ball.

Moisture content and specific gravity determinations were made on each test specimen.

As mentioned previously, the first series was confined to tests in static bending.

RESULTS.

Consideration will first be given to the results of the initial investigation, which was concerned with the timber irregularly stained with the brown discoloration.

To enable direct comparison to be made between the 'brown' oak and the 'normal' oak, correction of the results was necessary in two instances. In the first place the 'normal' oak tested green was lighter in weight than the corresponding 'brown' oak, although this disparity did not exist in the case of the air-dried material where the samples had been carefully cut from adjacent positions. From this latter result it was concluded that the discrepancy in the former case was due merely to the chances of sampling, and the recorded strength of these specimens was therefore increased to correspond to the slightly higher density. The second correction was required as the air-dried 'normal' oak was at 17·6 per cent. moisture content, whereas the corresponding 'brown' oak was at 15·5 per cent. To eliminate differences in strength to which this difference in moisture content would give rise, both the recorded values were corrected so as to correspond to a moisture content of 16 per cent.

The adjusted values are entered in Table I. The figures suggest that in the green condition the normal oak was the higher in bending strength by about 6 per cent., but that the advantage lay with the brown oak when the timber was at 16 per cent. moisture content to the extent of about 2 per cent. in bending strength and about 12 per cent. in stiffness. These differences are, however, comparatively slight and also inconsistent; in view of the very limited number

TABLE I. *Series I. Average Strength Values of 'Brown' Oak and 'Normal' Oak.*

Species.	*Moisture Content per cent.*	*Specific Gravity Oven-dry.*	*Static Bending.* *Maximum Bending Strength. lb. per sq. inch.*	*Static Bending.* *Modulus of Elasticity. 1,000 lb. per sq. inch.*
Green.				
'Brown' oak . .	Green	0·621	8,190	887
'Normal' oak . .	Green	0·621	8,710	878
Air-dried.				
'Brown' oak . .	16·0	0·605	11,790	961
'Normal' oak . .	16·0	0·607	11,580	859

of test specimens they may justly be ascribed to the chances of sampling. Further, no difference was observed in the type of fracture of the two groups of test pieces, nor did either exhibit any tendency to brittleness. The conclusion is reached, therefore, that the tests revealed no difference in strength or density between the brown discoloured wood in this plank and the oak of normal appearance. It is noteworthy that in density the wood exceeded the average of home-grown oak as previously tested in this laboratory.

In the second series the log from which the specimens were cut was brown throughout. In consequence the comparison in this instance is between the 'brown' oak and representative home-grown oak tested previously. The values representing the average of this log of brown oak are entered in Table II together with:

(1) values representing the average of home-grown oak, and
(2) values representing the average of the tree of lowest weight and strength encountered.

TABLE II.

Species.	*Moisture Content per cent.*	*Specific Gravity.*	*Static Bending.* *Maximum Bending Strength. lb./sq. in.*	*Static Bending.* *Modulus of Elasticity. 1,000 lb. per sq. in.*	*Toughness No. of lb.*	*Hardness Side.*
'Brown' oak . .	Green	0·48	5,770	796	102	860
Average of lightest tree of 'normal' oak	Green	0·50	7,280	1,073	No data	1,260
Average of 'normal' oak . . .	Green	0·55	8,140	1,290	140	1,060
'Brown' oak . .	12	0·54	10,350	1,037	62	850
Average of lightest tree of 'normal' oak	12	0·538	11,580	1,384	No data	1,218
Average of 'normal' oak . . .	12	0·61	13,340	1,560	97	1,230

Comparisons of specific gravity show that while brown oak was lower than the average of the species, it was equal (taking the average of green and 12 per cent. values) to the lightest tree observed. There is thus no definite evidence that 'brown' oak is characterized by sub-normal specific gravity.

The 'brown' oak is, however, shown to be consistently sub-normal in strength, both green and at 12 per cent. moisture content. As compared with the tree of 'normal' timber of equal specific gravity the inferiority of the brown oak ranges from 11 per cent. in static bending when at 12 per cent. moisture content to a maximum of 32 per cent. in hardness when green. Further, a marked degree of brittleness was revealed by the tests of static bending and toughness, which in itself suggests the presence of a wood-destroying fungus. In favour of the brown oak, on the other hand, it may be observed that the low values recorded under the hardness test signify wood very much milder and easier to work.

When considered together, the results of the two series of tests appear at first sight to be inconsistent. In the first experiment the 'brown' oak was found not to differ in strength from oak of normal appearance cut from the same plank. On the other hand, the second experiment revealed 'brown' oak to be markedly deficient in strength as compared with 'normal' oak of equal specific gravity. In view, however, of the irregular distribution of the brown discoloration it may be supposed that the fungus had not long been working in the timber from which the first samples were cut, while the uniformly brown colour of the subsequent material suggests an attack of long standing. While, therefore, these subsequent tests definitely suggest that the brown discolouring agent is ultimately detrimental to the strength properties of the timber, it is possible that its action is very much retarded in the early stages of infection, which would account for the negative results of the initial series of tests. Additional tests to compare the strength of brown oak in various stages of its development with that of normal wood would be necessary to settle this point definitely.

SUMMARY.

1. Mechanical strength tests were made on brown oak samples cut from (i) a partially infected log, (ii) a completely infected log.

2. In the first series of tests the 'brown' oak was found not to differ in strength properties or in density from adjacent 'normal' oak.

3. In the second series the 'brown' oak, though equal in density to timber from the lower extremity of the range of oak encountered previously, was definitely inferior in strength properties, being markedly softer and more brittle, thus suggesting the presence of a wood-destroying fungus.

4. It is suggested that these conflicting phenomena may be reconciled by adducing to the fungus wood-destroying properties which are of extremely feeble action in the early stages of infection.

The investigation described above was carried out at the Forest Products Research Laboratory, Princes Risborough, Bucks., under the direction of

Mr. W. A. Robertson, F.R.G.S., Director of Forest Products Research, by whose kind permission this account is published. The authors also acknowledge their indebtedness to their colleague Mr. K. St. G. Cartwright, M.A., D.I.C., whose investigation of the mycological aspect of 'brown' oak provided the opportunity for mechanical tests of the timber to be undertaken.

LITERATURE REFERENCES

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FOREST MANURING: A SURVEY

BY W. H. GUILLEBAUD
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I. THE POSITION ON THE CONTINENT.

THE large-scale employment of artificial manures in agriculture is of comparatively recent date—a mere matter of a century or thereabouts—but the success achieved has been so spectacular that it is scarcely surprising that now and then a forester should glance over the hedge at the crops of his agriculturist cousin, and ask himself if similar rewards might not be achieved in his own line of production, fundamentally different though it might be. Such an aspiration would be above all natural on the part of foresters whose charge included what may be termed the minimal types of forest soil such as coarse-grained diluvial soils, sour infertile loams, bad types of peat, and so on. It is for these classes of soils that the assistance of the Forest Research Stations of European countries has often been sought, and during the last 25 to 30 years the prescriptions have not infrequently taken the form of doses of one or more of the ordinary artificial manures: lime, nitrate of soda, basic slag, kainit, &c. When applying such manures the forester has undoubtedly employed them for much the same reason and from the same angle as his farming neighbour. On the assumption (supported by analysis) that his soil is markedly deficient in nitrogen, phosphate, and potash, he has added nitrate of soda or sulphate of ammonia to provide nitrogen, basic slag or superphosphate as a source of phosphate, and kainit or sulphate of potash to increase the supply of potash. When the forester has obtained what appeared to him definite results from one of these manures he has not unnaturally ascribed the improvement to the principal constituent of the fertilizer used, e.g. to phosphate in the case of basic slag, or potash in the case of kainit.

Recently, however, Dr. R. Lang of Munich (1) has published an interesting series of articles on forest manuring in which he points out that the matter is not quite so simple. In the first place, many of the minimal forest soils are poor almost beyond the conception of the agriculturist, and it is quite possible that beside the major plant food elements K, N, P, S, they may be lacking in other essential food constituents such as iron, magnesium, boron, manganese, &c.; secondly, when such a manure as basic slag is applied we are not merely giving the tree additional phosphate, but also very considerable quantities of other elements such as lime, iron, magnesium, &c. Similarly, kainit contains magnesium as well as potash, and sulphate of ammonia sulphur as well as nitrogen. The improvement in growth observed as a result of applying one or more of these manures may, in a given case, be due to one of the subsidiary constituents of the manure which happened to be in minimum in that parti-

cular soil. Again, Lang shows that such manures as basic slag and superphosphate, which contain a large amount of lime, are bound to be very complex in their reactions in the soil. Thus basic slag may act through (1) the manurial action of the phosphoric acid, (2) the specific action of phosphoric acid causing early ripening of shoot-growth, (3) the manurial action of the lime, (4) the neutralizing properties of the lime, (5) the iron and magnesium content. To these may be added as further complicating factors the variable composition of slag, and the degree of fineness to which it is ground.

That the analogy between the action of manures in the forest and in agricultural crops cannot be pressed too far is obvious also when the differences in the nutritional processes are remembered. Thus the nitrogen requirements of trees are normally met from the organic constituents of the humus in the absorption of which the mycorrhizas or fungal roots play an all-important part. The effect of a direct application of inorganic nitrogen compounds is thus likely to be very different when applied to trees or such field crops as wheat or potatoes.

The great majority of forest manuring experiments have been carried out in Germany, where the late Professor Schwappach was one of the earliest pioneers, but although many of the plots date back more than 20 years, until quite recently there was little but hearsay to go upon as to the results. Although reports on a few of the individual experiments have appeared from time to time in the German forest periodicals, it was not until Professor Wiedemann, Schwappach's successor at Eberswalde, had all the Prussian experiments reassessed and the work in other parts of Germany summarized, that it was possible to obtain a clear view of the position. In all, Wiedemann (4) was able to report on the results of 139 manuring experiments; of these 90 are new records in the sense either that the results had not previously been published, or that they relate to experiments which had not been assessed for many years. The remaining areas had previously been the subject of publication, many appearing in Professor Vater's useful summary (3) in *Arbeiten der Deutschen Landwirtschafts-Gesellschaft* in 1927.

The duration of the experiments ranges from 10 to 30 years with at least half the total established for more than 20 years. The majority include one or more sub-plots to which inorganic manures only were applied, but often cultural treatments of various kinds were included, such as the raising of lupin or broom, spreading of brushwood, ploughing in humus, &c. In a small proportion of the trials, cultural methods only were tested. Having such a relatively large number of experimental results at his disposal, Wiedemann was able to classify them on a broad regional basis as follows:

1. Poor sands of eastern Germany	. .	71 experiments
2. Better soils of eastern Germany	. .	3 ,,
3. North-west German heath region	. .	27 ,,
4. Central mountains of Germany	. .	38 ,,

As far as the action of inorganic manures is concerned, the outstanding fact is the very high proportion of negative results, but this is closely correlated

with the fact that most of the experiments were carried out with Scots pine which, under all conditions, appears singularly unresponsive to the application of artificial manures. Especially on the light sandy soils, the water-supply appears to be the dominant factor affecting growth; any local factor tending to improve the moisture relations may bring about an increase in growth far outweighing any small stimulus due to the manures applied. The chief positive results have been obtained by cultural measures such as lupin growing, intermingling of the humus layer and the mineral soil, and spreading of brushwood (*Reisigdüngung*). The only region in which a considerable proportion of the experiments deal with other species than pine is the fourth (Central Mountains). In that section there are over 20 experiments carried out with Norway spruce, but of these only 13 can be considered here. Of these, 6 were negative (in 2 out of the 6 sodium nitrate or fish guano only were applied; in the other 4 basic slag, either alone or in combination with potash and nitrogenous manures, was used). The successful experiments included one with ammonium phosphate, three with basic slag, one complete manure ($N+K_2O+P_2O_2+CaO$), one wood ashes, and one in which equally good results were obtained by applying either lime, basic slag, or kainit. The most spectacular results were obtained at Brandstein and Owinger. At Brandstein, where the soil was a stony loam over schist and with a dense growth of heather, the experiment was laid down in 1905. The main treatments in addition to the control were: (*a*) lime at the rate of 2 tons per acre, and (*b*) 2 tons of lime, 8 cwt. each of kainit and basic slag, and 3 top-dressings with sodium nitrate, each at the rate of 90 lb. per acre. At first there was little response, but after about 20 years the limed plot showed an increase in height of 25 per cent. and in volume of 100 per cent. compared with the unmanured control. In the completely manured plot, the increase compared with the control was 50 per cent. in height and 360 per cent. in volume. The cost of the liming was 20 to 40 marks per acre, and of the complete manuring 100 marks per acre.

The other experiment of special note is that at Owinger (2) laid out in 1906 and 1907 on a heavy loam. This experiment was fully assessed in 1932, that is after about 25 years' growth, and the production is given in the tables below.

Total Volume Production per Acre in Cubic Feet (true measure).

A. *Manured Plots.*

Lime.			*Basic Slag and Kainit.*			*Nitrogen.*		
Plot No.	*Manure.*	*Volume.*	*Plot No.*	*Manure.*	*Volume.*	*Plot No.*	*Manure.*	*Volume.*
1	16 Ca	1,440	3	6·4 P	3,160	5	1·6 N	1,640
2	8 Ca	1,530	4	6·4 P+3·2 K	3,180	6	1·6 N	1,790
8	8 Ca	1,990	9	6·4 P	3,370	11	1·6 N	2,140
15	16 Ca+Rye	2,300	10	6·4 P+3·2 K	3,310	12	1·6 N	2,370
20	16 Ca+Rye	2,580	16	6·4 P+3·2 K+Rye	3,480	..	..	..
..	..	..	21	6·4 P+3·2 K+Rye	3,700	..	..	..

The quantities of manures are given in hundredweights per acre.

B. *Control Plots.*

Uncultivated.		*Ploughed.*		*Ploughed and with preparatory crop of Rye.*	
Plot No.	*Volume.*	*Plot No.*	*Volume.*	*Plot No.*	*Volume.*
7	1,960	13	2,120	14	2,310
17	2,470	18	2,530	19	2,800

Even taking fully into account the rather variable soil conditions, which resulted in a natural fertility gradient, it is not possible to doubt the efficacy of the basic slag in increasing the volume production of spruce on this area.

Besides these experiments in which manures were applied to the young plants at the time of establishment, some interesting preliminary results have been obtained by the application of lime at the rate of 1 to 4 tons per acre to old stands of spruce and beech in the Erzgebirge, the stands selected having thick accumulations of raw humus. The effect of the liming has been to bring about a considerable decomposition of the raw humus which resulted in the invasion of *Oxalis* and other exacting plants.

Summary. Scots pine is virtually unresponsive to any of the ordinary artificial manures.

Norway spruce has shown in the majority of cases no response to potash and nitrogen; lime is effective only in doses of 20 cwt. per acre or over, and then by no means universally. Basic slag has in the majority of instances given definite improvement, but the order of increased growth obtained varies over a wide range. Only in a very few experiments has a major result been achieved.

The conclusion to which Wiedemann came in summing up the results at all experiments on which he reported was that the intercultivation of leguminous plants (perennial lupins on the moister spruce soils and yellow lupins on the dry pine soils) was both more certain and more effective than the application of any form of inorganic manures alone.

II. RECENT EXPERIMENTAL WORK IN GREAT BRITAIN.

Extensive manuring experiments with basic slag have been carried out by the Research Branch of the Forestry Commission since 1924 in Great Britain. Most of these deal with poor or bad soil types, but a certain amount of information is available as to the effect of this manure on moderately good ground. The Research Branch data are amplified to some extent by divisional experiments, notably in Scotland, SW. Division.

It has not been possible to distinguish between the effect of basic slag when applied to the roots of the trees at the time of planting and that of application to the surface of the soil round the base of the plant, either immediately after planting or within 1 or 2 years of the date of planting, although both methods have been used in the experimental work. In either case improved shoot growth does not appear until the second growing season after application, and the order of response appears to be very much the same, given equivalent doses of

basic slag. While this may hold good in experimental work where the manure is applied very carefully, in large-scale work there is a common tendency in top-dressing to dump the slag in small heaps at the base of the plant. These become crusted over and can be found apparently unaltered many years after the slag was applied. Unless the slag is thinly sprinkled round the plant, application to the roots at the time of planting is likely to be more effective, for a given quantity of slag.

The available information, published here by permission of the Forestry Commissioners, may be summarized as follows:

I. Peat Soils.

1. *Turf planting. Basic slag applied at time of planting or very shortly after planting.*

(i) *Grass-Juncus and Grass types (other than Molinia).* Beddgelert (North Wales) No. 5, P. 27.[1] Growth of Sitka spruce and Norway spruce without slag has been excellent. Little sign of response to the manure.

(ii) *Molinia types.* There are corners of *Molinia* ground in some of the experiments. Growth of the spruces is generally equally satisfactory with or without slag.

(iii) *Eriophorum types without much Calluna or Vaccinium.* At Dalbeattie, Kirkcudbrightshire, an area was planted in P. 28 with Sitka spruce. Unmanured plots are as good as the manured. The same applies to ground of this type in Beddgelert No. 5, P. 27. Sitka spruce are also growing well without slag in North Tyne No. 1, P. 27.

(iv) *Eriophorum types with Calluna and±Vaccinium, but with little or no Scirpus.* Sitka spruce, Scots pine, and Japanese larch were planted without slag in North Tyne No. 7, P. 28. The two former species are coming out of check but the Japanese larch are still checked.

On somewhat better ground of the same general type in North Tyne No. 14, P. 30, Norway spruce and Sitka spruce without slag are as good as the manured plants. In another experiment at North Tyne No. 12, P. 29, on *Eriophorum-Calluna-Vaccinium* the following shows the position after 4 years' growth:

	Sitka Spruce.		*Pinus Contorta.*	
	Height (inches).	*Shoot (inches).*	*Height (inches).*	*Shoot (inches).*
Unmanured . .	11·3	1·5	9·3	4·2
1 ounce slag . .	16·1	2·8	10·9	5·4

The basic slag is helping the Sitka spruce but it may be only a question of time before the control plants get away; the *P. contorta* are doing practically as well without manure.

[1] In this notation the first figure (5) relates to the number of the experiment in the forest named, while the succeeding letter and figures (P. 27) relate to the planting year in which the experiment was established, in this case the winter of 1926–27.

(v) *Scirpus types rich in Eriophorum, Erica Tetralix, and Molinia.* Sitka spruce planted on ground of this type at Beddgelert showed a marked response to the application of basic slag, e.g. Experiment 5, P. 27, where the position at the end of 1932 (6 years' growth) was as follows:

Treatment.	*Total Height (inches).*	*Shoot Growth. Percentage Distribution in Shoot Classes.*			
		0–5 inches.	*6–7 inches.*	*8–10 inches.*	*Over 10 inches.*
No manure . .	16	98	2	..	..
1 ounce basic slag .	37	18	19	41	22

The unmanured plants were still in check while the manured plants gave promise of becoming established.

(vi) *Scirpus-rich types with much Erica Tetralix and stunted Calluna.* (*a*) *Basin types—i.e. peat accumulated in depressions.* Experiment 7, P. 27, at Beddgelert, is situated on one of the best varieties of this type, i.e. one with dominant *Scirpus* but with much *Eriophorum* and little *Calluna*. Species, Sitka spruce. After 5 years the control plots were still mostly checked, while the manured plants were making relatively good growth. The assessment showed that 95 per cent. of the plants in the control were putting on shoots of less than 2 inches, and only 2 per cent. had shoots of 6 inches and over, while the corresponding figures for the manured plots were 22 per cent. and 30 per cent. respectively.

The poorer and more typical ground of this *Scirpus-Calluna* type is well exemplified in the large Lon Mor bog on Inchnacardoch Forest, near Fort Augustus, Inverness-shire. Here many experiments have been carried out with different species. The results are as follows:

(*a*) *Sitka spruce.* Experiments in which basic slag was used date from 1925 onwards. The ground in general varies in quality with the distance from the slopes above the bog. Even although these slopes are of *Scirpus*-clad moraine over quartzite, the ground near its foot is better than that in the centre and near the slight ridge which forms the south-eastern boundary of the bog. The earlier experiments (P. 25–P. 27) were mostly on the worst type. The general results on the poorest ground may be stated as follows: No response in the 1st year; a definite improvement in the 2nd year; the effect reaches its peak in the 3rd year, when shoots of from 6 to 10 inches are put on by a small proportion of the plants, the average shoot being from 3 to 4 inches. In the 4th year growth falls off, the average shoot being about 2 inches, in the 5th and subsequent years the plants revert to a more or less completely checked condition, but still carry a fairly large amount of foliage, the needles being of medium length and more or less normal colour. The future of these plants is quite uncertain; they may eventually recover and start to grow or they may go more and more back and finally die. Unslagged control plants are completely in check and are much poorer than those which received the manure.

Another phosphatic manure, Semsol, may be mentioned here, as in one

experiment, No. 43, P. 28, it has given better results than basic slag, and has maintained growth up to the 6th year.

The assessment at the end of 5 years' growth gave the following data:

Treatment.	*Average Height (inches).*	*Average Shoot (inches).*
Control—unmanured .	7	<0·1
2 ounces basic slag . .	14	1·4
3 ounces Semsol . .	20	4·1

The data show that the control plants are not growing at all in height, the plants treated with basic slag are going back, while growth in the Semsol treated plots is so far being maintained, although it is doubtful if it will continue at the present level. By re-slagging it may be possible to get Sitka spruce into canopy on the better facies of this type of peat, but the experiments have not been going long enough to be definite on this point. In Experiment 74, P. 29, a second dose of slag applied the year after planting maintained the average shoot growth at the end of 4 years at a level of 6 inches as compared with the average of 5-inch shoots in the case of plants over-slagged; the difference is not really appreciable. The peat here is of rather better type, but it remains to be seen how long satisfactory growth will continue. In another experiment on worse peat (12, P. 25) redressing has had virtually no effect in bringing the plants out of check.

The results may be summed up by stating that the effect of basic slag applied to Sitka spruce on the Lon Mor type of *Scirpus-Calluna* peat appears to be only transitory as far as shoot growth is concerned. The future development of the plants is still problematical.

(β) *Norway spruce.* Mr. J. M. Murray has supplied two interesting cases from Inverliever. In the first of these the ground was planted in P. 23 with 2 ounces of basic slag per plant. Growth was good until 1926, when check began; in 1927 some drains were deepened and part of the ground re-slagged. Position is as follows (after 10 years' growth):

Sections.	*Height of Plants. (inches).*	*Current Shoot (inches).*	*Condition.*
1	Drains not deepened: one application of slag		
	20	2	Healthy
2 and 3	Drains deepened: two applications of slag		
	44	7½	Very healthy
	34	6½	„ „
4 and 5	Drains deepened: one application of slag		
	20	1¼	Healthy
	14½	2	„
6	Drains deepened twice: two applications of slag		
	46	9¾	Very healthy

In this case re-slagging combined with opening out some of the original

turf drains bids fair to get the plants out of check, but there must still be some uncertainty as to the future.

The second experiment at Inverliever was planted in P. 26 and slagged immediately after planting. Drains were close and deep. The slag was effective for about 3 years, but the current shoot growth ranges from ¾ to 2 inches and the plants are mainly yellowish.

Very little Norway spruce has been planted on the Lon Mor peat bog, but what there is is checked and unpromising in spite of the use of basic slag.

(γ) *Japanese larch.* There are only a few plants of this species on the *Scirpus* peat of Lon Mor. The plants responded well to the application of basic slag; after 6–7 years the effect is still observable and they are decidedly more promising than either of the spruces. The unmanured controls are poor, less than one-third of the height of the slagged plants.

Pinus contorta on Basin Scirpus Peat. This species has been planted over an area of several acres on the Lon Mor in an experiment dealing with methods of turfing and draining. All the plants received slag at the time of planting so there is no direct evidence as to the effect of the manure. The plants, after 6 years' growth, are still vigorous (average height over 3 feet) and growth is not apparently falling off.

(*b*) *Climatic or Slope Peats—Scirpus types.—Sitka spruce.* Broadly speaking, the reaction of Sitka spruce on this type of ground to the application of basic slag is very similar to that on the Basin types. The effect in the 2nd and 3rd years is perhaps a little more marked, but as a rule growth falls off again quickly in the 4th and 5th years after slagging. The unmanured controls in all cases remain completely checked. There is a complete lack of evidence as to the ultimate recovery of either the manured or unmanured plants; the manured plants, although more or less checked, after 5 or 6 years' growth have more foliage, longer needles, and a much more extensive root system than those which received no manure.

Japanese larch. There are manuring experiments with Japanese larch on slope peats at Inchnacardoch, at Achnashellach, Ross-shire, at Glen Righ, Inverness-shire, and elsewhere. The outstanding experiment is No. 9, P. 28, at Achnashellach, where alternate manured and unmanured strips run down to the foot of a slope; the ground is towards the good end of the series of *Scirpus* types. Drainage was intensive, turf drains being only 12 feet apart. After 6 years the manured plants average 5 feet 4 inches in height with a mean shoot of 18 inches as compared with 2 feet 2 inches height and 4-inch shoots in the control sections. In most places the manured plants are already in canopy and there is no sign of any check setting in.

Another experiment, 7 C, P. 28, on rather poorer ground at Achnashellach, has given generally similar results: manured plants 4 feet high and 12·4-inch shoot, controls 2 feet high and 3·5-inch shoot.

At Inchnacardoch, basic slag has produced equally definite results, e.g. No. 36, P. 27, was top-dressed after one season's growth and part also again manured in the 2nd year. Control plants average 18 inches high with 1-inch

shoots. Plants top-dressed once are 32 inches high with 5-inch shoots. Those top-dressed twice are 47 inches high with 7-inch shoots. Again, in No. 62, P. 28, where the plants were top-dressed the year after planting, the growth at the end of the fourth year was:

	Height (inches).	*Shoot (inches).*
Control	15	2·3
Slagged	40	9·8

These data for Japanese larch give far greater promise of successful establishment with the aid of basic slag than is apparent in the case of the spruces. Without basic slay the success of Japanese larch on the slope *Scirpus* types is problematical, and probably at least 10 years of check must be reckoned with. Basic slag reduces the death-rate appreciably and can, as we see at Achnashellach, bring the crop into canopy in as short a space as six years.

Pinus contorta. This species was planted in manurial trials in P. 28 both at Inchnacardoch and at Achnashellach, and in both areas shows a marked response to basic slag, e.g. at Inchnacardoch (in No. 62, P. 28) after 5 years the manured plants averaged 2 feet 6 inches in height with shoots of 8·8 inches as compared with 17 inches in height and 4·8-inch shoots in the control. Present indications are that *P. contorta* without slag grows more freely on the slope peats of the *Scirpus* type than any other species, and although on the worst types it may be desirable to apply basic slag, it seems possible that on the rather better types it may establish itself unaided except by turfing with intensive drainage.

Alnus oregona. This species has been planted in P. 30 and P. 31 in the heavily drained and closely spaced turf groups on slope peat at Inchnacardoch, basic slag being used. It grew well in the 2nd year, and after 4 years is still making good progress. The P. 33 shoots of a number of plants measured each year averaged 17 inches. There are no unmanured controls, but judging by experience in North Wales the trees are not likely to start well without the aid of basic slag.

2. *Turf planting. Basic slag applied several years after planting when it is apparent that the plants are in a state of check.*

The evidence as to the effect of delayed application of basic slag to turf-planted trees is somewhat limited. Probably the most definite results have been obtained by Sir John Stirling-Maxwell at Corrour, where slag was applied broadcast at rates varying from 10 cwt. to 30 cwt. per acre to turf-planted Sitka spruce which had checked on *Scirpus* types after an initial dose of slag some 6 to 10 years previously. These fairly heavy broadcast dressings have been generally successful in getting the trees out of check, and in many cases the

plants now appear to be established. No analogous cases on Commission areas are known to the writer; for one thing our turf-planted areas are mostly too young to provide strictly comparable conditions. Again, as a result of an investigation recently carried out at Inchnacardoch into the root structure of Sitka spruce and other species turf-planted with and without basic slag, it appears probable that the broadcasting of basic slag would have a far greater effect on plants which had received a dose of slag on planting than on plants which got no manure originally. In the one case a well-developed surface root system exists, capable, presumably, of utilizing the slag, while in the other the root system is virtually restricted to the turf itself. (These remarks apply primarily to the *Scirpus-Calluna* peat types.)

3. *Direct Planting.*

There are considerable areas of peaty ground which were planted with spruce by the ordinary notch method in the years P. 21 to P. 26 and in which the trees are still for the most part checked. Basic slag has been applied on an experimental scale to a number of these plantations, but not as a rule with any very striking results. A better colour usually results and the stronger plants may show slightly improved growth, but as a rule the response has been disappointing.

On moderate types of ground, drainage is normally all that is necessary to get spruce out of check, while on the bad types, unless an improvement in the vegetation can be brought about by intensive drainage, the additional application of basic slag is not likely to be effective.

II. Mineral Soils with a Calluna-rich Vegetation (less than 6 inches peat).

(i) *Calluna types with a fair admixture of fine grasses.*

(*a*) *Effect of basic slag applied within a year or so of planting.* Almost the only experiment on this type is No. 1, P. 29, at Hamsterley, co. Durham, where Scots pine, *Pinus contorta*, Japanese larch, and European larch were planted at an elevation of nearly 1,100 feet on a heavy loam. Basic slag has had a marked effect upon the growth of the two larches—much more so than in the case of the pines. After 3 years the position was as follows:

	Japanese Larch.		*European Larch.*	
	Control (inches).	*Slagged (inches).*	*Control (inches).*	*Slagged (inches).*
Average height . .	5	13	11	18
Average shoot . .	1·4	7·1	2·0	5·1

The experiment has not run long enough to be of much value, but the poor growth of the unmanured plants will be noted. By analogy with results on other vegetation types, it would seem probable that the manured Japanese

larch will now go ahead. One further point of interest is that losses were considerably lower in the slagged larch plots. It is a common experience that a proportion of larch plants planted on *Calluna* ground hang on for a year or two and then die: an application of basic slag at the time of planting saves the majority of these weakly plants.

(*b*) *Effect of basic slag applied several years after planting.* An area of Norway spruce planted at Kerry Forest (Mid-Wales) in P. 25 was top-dressed with 4 ounces of basic slag in 1929. The site was very exposed and the plants show marked evidence of wind-blast. The slagged plants are not appreciably better than the controls, and both are growing at the rate of about $3\frac{1}{2}$ to 4 inches per annum. The soil is a loam.

A similar experiment at Llanover on Norway and Sitka spruces planted in P. 25 also gave negative results as regards the effect of basic slag, although in this case the Sitka spruce have emerged from check and are now growing quite normally. Examination of the shoots showed that the Sitka spruce were more or less in check up to 1929 and that normal growth began in 1930 all over the area. The Norway spruce are still checked and the slag seems to have had little effect on the treated plants.

At Halwill, Devonshire, however, basic slag has had a definite effect upon Norway and Sitka spruces planted in P. 23 on a Dwarf-gorse-Heather-*Molinia* type. (This is really a separate type but for convenience is considered here under *Calluna*—Fine Grasses.) Four ounces of slag were applied in 1929. The present position is as follows:

Treatment.	*Sitka Spruce.*		*Norway Spruce.*	
	Mean Height (inches).	*Mean Shoot (inches).*	*Mean Height (inches).*	*Mean Shoot (inches).*
Control . . .	12	0·6	12	0·6
Slagged . . .	31	6·2	27	6·0

After 10 years' growth the control plants are still in check, while the slagged plants have every appearance of getting away. The slag has affected the vegetation, improving the growth of the gorse which now tends to dominate the heather; in the control sections the heather is holding its own with the gorse.

(ii) *Calluna types without fine grasses.*

(*a*) *Planted on the natural surface. Effect of basic slag applied within a year or so of the date of planting.* Such experiments as there are of too recent date to consider at present.

(*b*) *Planted on the natural surface. Effect of basic slag applied several years after planting.* At Cynwyd, North Wales, Norway spruce was planted in P. 26 in a moderately exposed site at 1,400-feet elevation. Alternate strips were slagged in 1929. The slag has slightly improved the general appearance of the

plants but the effect on growth has been inappreciable, as may be seen from the following data:

	Mean Height (*inches*).	*Mean Shoot* (1933) (*inches*).
Control . . .	14	1·1
Slagged . . .	14	1·4

The influence of the slag was more marked 2 years ago, so the effect appears to be already wearing off.

At Allerston, Yorkshire, slag applied to Sitka spruce planted about P. 24 and in check has been wholly without result.

Having regard to the peculiarly tight surface of most of the poorer *Calluna* soils it seems possible that the ineffectiveness of basic slag applied as a top-dressing may be due to the manure being held up on the surface. Better results might be obtained if the surface crust were broken to allow the slag to penetrate into the soil.

(*c*) *Ploughed ground. Basic slag applied within* 1 *or* 2 *years of planting.* The oldest experiment is that at Allerston (No. 6, P. 28), part of which was top-dressed with slag at the rate of 2 ounces per plant applied 2 years after planting. The soil is a heavily leached, compacted sand, over clay.

Position at end of 1932 was:

	Scots Pine.		*Corsican Pine.*		*Japanese Larch.*		*Sitka Spruce.*	
Treatment.	*Height* (*inches*).	*Shoot* (*inches*).	*Height* (*inches*).	*Shoot* (*inches*).	*Height* (*inches*).	*Shoot* (*inches*).	*Height* (*inches*).	*Shoot* (*inches*).
Control . .	14	2·2	10	3·0	10	1·7	16	2·4
Slagged . .	18	4·6	16	6·1	16	4·4	22	4·9

Growth of all species has been relatively slow, and it is too soon to prophesy as to the lasting qualities of the stimulus provided by the slag. An examination of the roots has shown—especially in the spruces—a much increased root development where slag had been applied; the roots also of the slagged plants were actively growing while the control plants were dormant (examination made in September 1933). In other experiments with basic slag at Allerston, in P. 29 and P. 30, improved growth of the following species was obtained: European larch, Japanese larch, Scots pine, *Pinus contorta*, Sitka spruce, Grey alder, and birch.

At Harwooddale near Scarborough, Ringwood in Hampshire, and Wareham in Dorset (leached sandy soils), all species of conifers tried have responded to the application of basic slag on ploughed or dug-over ground. The effect is particularly marked on seedlings. Data are not given as none of these experiments has been running for more than 3 or 4 years. At Teindland Forest in Morayshire extensive experiments have been carried out with basic slag on

ploughed ground or in dug-over groups. The soil is a heavily leached, fine sand over boulder clay. There is a definite tendency on the part of the spruces to slow down in growth and become yellow after the first effect of the slag has worn off. The effect on the pines is more persistent, *P. contorta* being outstanding in this respect. Here again the experiments have not been going long enough to enable any final judgement to be made.

Summary of Experimental Work in Great Britain.

Basic slag appears to have relatively little effect upon the early growth of plants planted on the better types of peat and of mineral soil. Used on really bad (*Scirpus-Calluna*) peat types, the effect is very marked for 3 or 4 years, but what happens after that depends largely upon the species. The spruces as a normal rule go back into check, but so far not into the same hopeless-looking check as the unmanured control plants. Root investigations indicate that the slagged plants have a much better developed root system, and they may ultimately resume growth and form canopy, but on present evidence, the process, if it ever takes place, is likely to be a slow one. Japanese larch and *Pinus contorta* show a more sustained response to basic slag, and in one case (Achnashellach, 9, P. 28) canopy has actually been formed in 6 years from the date of planting. The control plants in this area are not thriving, and there is some justification for the conclusion that the basic slag has made a crucial difference. This stage has not been reached with any of the *Pinus contorta* plots on bad peat types. At present it is impossible to say (*a*) whether the effect will be lasting, or (*b*) whether the unmanured controls may eventually establish themselves. Between the two extreme types of peat soils, there is no doubt an intermediate class where the addition of slag may reduce a period of check from say 10 to 15 years down to only 2 or 3 years. Probably a complex of locality factors is involved, and it is likely to be some time before most of these types can be recognized with any certainty.

The relative advantages of slagging at the time of planting (slag placed at the roots), shortly after planting, and several years after planting, are not known with any certainty where turf-planted trees are concerned. In each case a definite response is more or less assured (on bad peat types). On the whole, use at the time of planting is likely to be the most economical method, but against this can be set the possible use of slag on ground which does not really require it. The top-dressing of plants direct notched on peat does not appear to be generally effective.

As regards the mineral soil types, the species which are most liable to check on *Calluna*-Fine Grasses are the larches and spruces. Existing experiments on this type of ground are rather few, but the evidence suggests that a certain amount of beating-up might be avoided by the use of slag at the time of planting, and also that the check period could be appreciably lessened. In one instance the top-dressing of plants severely checked on a Dwarf-gorse-Heather-*Molinia* type has been successful in bringing these out of check. The experiments on the poorer types of *Calluna* ground, whether ploughed or un-

ploughed, are still at a stage at which any final judgement would be premature. The reaction of the different species to applications at the time of planting is much the same as on the poorer peat types, i.e. the spruces make a good start and then tend to go back, while in the case of Japanese larch and the pines the stimulus lasts longer, and so far the plants are retaining most of their increased vigour.

The top-dressing of spruces checked on unploughed *Calluna* ground has not been effective, and it is suggested that the slag is unable to penetrate the crust which so often forms on the surface of these soils.

The relation of effect produced to quantity of slag used is a matter of some interest. The normal application at the time of planting has been 2 ounces of slag per plant. In some of the experiments 1 ounce only was used—the initial stimulus appears to be about the same with both doses—but there is some evidence to suggest that the effect of the larger application may be more lasting. Recently several experiments have been laid down dealing with this question.

General Summary.

1. The results of a large number of manuring experiments on the continent of Europe are discussed and it is shown that the application of inorganic manures has effected a definite improvement in growth in only a small proportion of the experiments. Scots pine in particular has proved unresponsive to chemical manures. The few spectacular results have been achieved with Norway spruce manured with basic slag (or lime). Attention is also drawn to the probably complex action of most of the commercial fertilisers.

2. Preliminary data are given regarding recent manuring experiments carried out in Great Britain on different types of peat and podsolized mineral soils. In almost all cases the manure used was basic slag, which was applied at the time of planting to a number of species, including Sitka spruce, Japanese larch, and *Pinus contorta*. Within somewhat narrow limits both as regards soil and species, it appears that manuring with basic slag may be of definite value in promoting the establishment of trees on certain difficult types of waste land.

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(4) Wiedemann, E.: 'Der gegenwärtige Stand der forstlichen Düngung.' *Arbeiten der Deutschen Landwirtschafts-Gesellschaft*, vol. ccclxxxv, 1932. [Includes a comprehensive list, with 80 references to literature on forest manuring (excluding nursery work).]

THE OCCURRENCE OF THE LONGHORN BEETLE, *HYLOTRUPES BAJULUS* L., IN ENGLAND

BY E. A. PARKIN

(Entomology Section, Forest Products Research Laboratory)

SEVERAL instances of damage by *Hylotrupes bajulus* to softwood roof timbers have recently been investigated by the Forest Products Research Laboratory. Since this beetle is of considerable economic importance on the Continent, but has, up to the present, been found only rarely in this country, the present note has been written to give a general account of the life-history and habits of the insect, with detailed information on the results of inspection of three infested roofs.

The Longhorn beetles (family Cerambycidae) normally attack only green timber, but there are a few exceptions to this general rule. Of these, the most important in Europe is *Hylotrupes bajulus*, which occurs in all northern European countries, particularly those round the Baltic Sea. Particular attention is now being given to this insect in Germany and Denmark, and a report (1) recently issued from Copenhagen shows that extensive damage is being done to the seasoned softwood roof timbers of many Danish municipal buildings and private houses. The insect seems to have become really injurious only during the last 50 years but is now a cause for grave concern. In view of the large quantities of softwoods imported from the Baltic States, there has for some years past been the possibility that *Hylotrupes* would be introduced into buildings in this country by the use of infested timber.

The presence of *Hylotrupes* in England has already been recorded by Fowler (2): '. . . In old posts, rails, &c.; rare; Forest Hill; Weybridge; Belvedere; Hammersmith, in orchard trees; Epping; Hertford; Suffolk; Deal; I have specimens in my collection taken by Lady Maryon Wilson about the year 1795.' It is evident from these records that *Hylotrupes* can live in the open in this country, but, so far as is known, there have been no instances recorded of its damage to structural timbers in houses.

The beetles (Fig. 1) are 7–25 mm. long, the females usually being larger than the males and further distinguished by the presence of a short tubular ovipositor projecting behind the elytra. The mature beetles are black, but thick grey pubescence covers most of the prothorax and forms four spots on each elytron: these spots may, however, become fused so as to give rise to two transverse grey bands. The antennae are about one-half the length of the insect and are relatively slightly longer in the male than in the female. A very characteristic feature of *Hylotrupes* is the presence upon the prothorax of two smooth, shining, black prominences, one on either side of the median dorsal impression.

The eggs are usually laid in cracks and crevices in the wood, average 30–40 but may rise to 60 per female, and hatch in about 14 days. The larvae are typical longhorn grubs, white, fleshy, somewhat flattened above and below, having the legs but slightly developed, and attaining a length of 20–30 mm. The head is sunk in the prothorax so that only the brown mouth parts are visible, and has on either side three very small ocelli which are characteristic of this genus. The larval period lasts about 4 years, during which time the larva is boring in the wood. The fully grown larva gnaws a pupal chamber near the surface of the wood and there changes into the pupa from which the beetle emerges some 14 days later.

Only softwoods are attacked and the sapwood is always tunnelled first: the heartwood, however, is not immune from injury.

Apart from the three cases investigated by the Laboratory, which will be detailed later, some information upon the occurrence of *Hylotrupes* in structural timbers in this country has been communicated by Mr. F. Laing, M.A., B.Sc., Department of Economic Entomology, British Museum (Natural History), and I am grateful to him for permission to publish it here. He states that he has had sent to him from time to time specimens which presumably have emerged from imported timber: the beetle was sent in perhaps more frequently during the period 1920–5 than more recently. He has three records of attack in old buildings, namely, in 1925 (Balham area), 1928 (near Kidderminster), and 1930 (Kensington area), where the roof timbers were burrowed badly. The timbers were very severely damaged in the Kensington property, and a large quantity of wing-cases and bits of beetles had been brushed up by the contractor's men: it seemed as if the beetles might have been at work for some time. The attack, however, had died out in all three buildings before repair work took place.

In April 1934 an inquiry was passed to this Laboratory by the Secretary, British Wood Preserving Association, in which a householder had discovered living beetles emerging from the roof timbers of his house near Walton-on-Thames, Surrey, in August 1933. Some of the dead beetles were forwarded and were identified as *Hylotrupes bajulus*. Arrangements were immediately made for an inspection of the infested roof in order to trace, if possible, the origin of the attack and to obtain first-hand information on the type of damage caused. The house was built 24 years ago and has three stories; it is semi-detached and adjoins a similar building occupied since its construction by a firm of grocers and provision merchants. *Hylotrupes* attack was evident in the Memel fir (*Pinus silvestris*) rafters and ceiling joists, in some of the ceiling laths, and in the framing of the ceiling light above the stairs. Several large piles of fresh bore-dust were seen beside or below infested timbers. The damage (Fig. 2) superficially resembled that caused by *Lyctus* in hardwoods, in that the sapwood was completely powdered beneath a thin skin of apparently sound wood. Large oval exit-holes were present in many of the attacked timbers, and all looked newly made. The roof was not infested throughout, but the attack was distributed in patches. It is interesting to note that a glass

light was present in the slated roof nearly above the ceiling light, and the attack was spread through the roof timbers quite independently of light or shaded positions. It has already been mentioned that the house in question was constructed 24 years ago, and since that time no new wood has been added to the roof. According to various authors the normal life-cycle of *Hylotrupes* on the Continent occupies 4–5 years and, since living beetles emerged in August 1933, the infestation must have started in 1929 or before. The possibility must be considered, however, that the larvae have been in the wood for 24 years, and have only just completed their development. There are records of *Hylotrupes* taking 11 and 17 years to attain the imaginal state, but 24 years represents rather a big increase in time over these periods. Furthermore, to judge from experiments with other wood-boring beetles, larvae which have had a long struggle for existence in unsuitable timber usually produce undersized adults, but the beetles sent to the Laboratory appeared to be of normal size. Had the insects been breeding normally in the wood during the past 24 years with a 4-year life-cycle and the females laying 30–40 eggs each, the damage to the roof would no doubt have been much more severe than was evident during the inspection, but conditions in the roof may not have been suitable for quite such rapid multiplication. It is impossible, therefore, to trace definitely the origin of infestation and to say whether it was originally present in the wood or whether beetles possibly found their way into the roof from Danish egg and butter boxes which are piled in the small adjoining garden of the grocery stores for periods up to about a week, or, alternatively, changed from attacking posts, &c., in the vicinity to damaging structural timbers.

Another complication was added to the problem of this occurrence of *Hylotrupes* when, during the course of conversation, the owner mentioned that a friend had had to renew the whole of his softwood roof owing to insect attack. This second house stood about 100 yards from the first, on the opposite side of the road, with other houses intervening: it was detached and had been built some 40 years. The owner was interviewed and he stated that attack was first noted in summer 1932 when electric light was being installed. The damage then was sufficient to cause the owner to decide that replacement was necessary. All the roof timbers were removed and renewed with the exception of one purlin, which was considered sound. This purlin was carefully examined during the Laboratory inspection and two small piles of wood-dust were found. This was collected, compared at the Laboratory with the frass of *Hylotrupes*, and found to be identical. An examination of a wooden workshop in the garden also disclosed the presence of badly infested timbers, the tunnels and frass therein corresponding to that of *Hylotrupes*.

It was maintained that, during the renewal of the roof timbers, no dead or living beetles were found though larvae were present in the wood. This being the case, the only possible explanation would seem to be that infestation was very severe, but had been discovered before the larvae had completed their development. If it is assumed that the beetles would have emerged during

PLATE XIV

FIG. 1. *Hylotrupes bajulus*, L. Male (× 8)

FIG. 2. Joists (*Pinus silvestris*) showing *Hylotrupes bajulus* damage. (× $\frac{1}{3}$)

the next year, i.e. summer 1933, it is quite possible that the two houses were infested at the same time from the same source of beetles. Unfortunately, it was not possible to examine the roof of the building occupied by the grocers, nor were those of other houses inspected, but it is quite likely that more houses in the neighbourhood are affected than the two mentioned.

During June 1934 another inquiry was received by the Laboratory when a sample of bore-dust and a very small piece of wood were sent from the deal (*Pinus silvestris*) roof timbers of a church in the Richmond (Surrey) district. The bore-dust and damage appeared to correspond with that of *Hylotrupes* and an inspection of the roof was made in order to confirm this.

The church was built about 100 years ago, and had softwood roofing timbers, hidden from below by a plaster ceiling and covered above by slates without roofing boards. Ventilation was effected through two apertures in the wall at the west end which were made about three years ago when the ends of some of the principals had to be renewed owing to decay consequent upon leakage of water into the roof from defective guttering. Apart from the repairs then carried out the roof was strengthened by the addition of new timbers some twelve years ago because the span was considered too great for the existing members. No information was available as to which were new and which were original timbers, but it is possible that *Hylotrupes* was introduced with the strengthening timbers. All the attacked members were principal rafters: these principals, incidentally, were double, an upper and a lower member being present on both sides of each truss. One principal was seriously damaged and showed numerous exit-holes: several other similar timbers were also infested but not very severely. Attack was confined to the sapwood and extended 1–2 inches into the wood from the surface. The exit-holes did not look very recent, and it was evident that the insect had been at work in the timber at least 4 years and possibly 8 years or more. No signs of living or dead beetles or grubs were seen and it was impossible, therefore, to establish the identity of the insect with absolute certainty, but from examination of the type of tunnelling, shape and size of exit-holes, and by comparison of the bore-dust with that of *Hylotrupes*, there can be little doubt that *Hylotrupes bajulus* was the cause of the damage. One place was noted where the wood had been tunnelled on one edge with no signs of an exit-hole, and this suggests that attack is possibly still active in the church.

It is a pity that it was impossible in the instances of attack investigated by the Forest Products Research Laboratory to arrive at any definite conclusions with regard to the origin of attack. There is no doubt, however, that *Hylotrupes* can breed successfully in seasoned softwood structural timbers in this country and, indeed, that it has settled down to do so in a number of buildings over a wide area. In view of the quantities of softwoods which are now used in house and other constructional work, the possibility of *Hylotrupes* spreading and causing extensive damage to such structural timbers in this country must be borne in mind.

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AN INSTANCE OF EARLY INFECTION OF WHITE PINE (*PINUS STROBUS* L.) BY *TRAMETES PINI*

BY W. R. HADDOW

(Department of Botany, the University of Toronto)

AMONG the wood-rot diseases of conifers, that caused by *Trametes pini*, known variously as red rot, red stain, white pocket rot, ring scale, conk rot, &c., is certainly the most destructive. It is the cause of immense forest damage which materializes as cull and degrade in mature stands.

Heart-rots generally are regarded as diseases of mature and over-mature timber, and *Trametes pini* rot is not considered exceptional. This opinion derives, it may be presumed, from the common observation of the prevalence of rot in older stands. That the damage occurs largely in timber of merchantable size cannot be doubted, but that young stands are free of the disease is an unwarranted assumption. It must not be forgotten that the pathological condition begins with infection, and not with the appearance of major symptoms after the disease has reached an advanced and chronic stage. For purposes of control it is important that there be full appreciation of the age at which trees become susceptible.

During the course of studies of *Trametes pini* rot of White pine, the writer had encountered unexpected cases of infection in young trees, a fact which presents this disease in a new light. One of these cases is recorded herewith in some detail.

A diseased tree was discovered in an isolated stand of White pine near the Durham County Forest in southern Ontario. The stand had been established somewhat irregularly by natural regeneration from scattered seed trees of large size, none of which have survived. The trunks of several now lie on the ground in an advanced stage of decay, and show conspicuously the symptoms of *Trametes pini* rot, although such is not now progressive, if indeed the fungus still survives. But it was doubtless from sporophores on these trunks that the infection of the present stand originated years ago. The trees now occupying the ground range in age from 50 to 70 years, and although many are infected, fructifications of the fungus are not at all common, and were actually found only on dead trunks.

One of the most characteristic and interesting symptoms of *Trametes pini* rot is the so-called *punk knot*, a mass of brownish friable substance which develops around embedded branch stubs as a result of infection at or near the cambium. The first *punk knot* is formed at the stub through which infection takes place. When the mycelium of the fungus has grown in the trunk to the vicinity of other stubs, other knots may be formed. The *punk knot* substance is composed not only of the various types of hyphae of the fungus, but of

fragments of modified wood, of the rhytidome of the bark, and of remnants and substance from callus proliferated from the cambium and meristematic tissue of the bark. Thus the *punk knot* grows with the tree, and constitutes a fairly accurate chronology of the infection.

Incipient infection is present of course before *punk knot* develops. Hyphae from a germinated spore grow through the embedded stub into heartwood with which it is continuous. Exactly how the encircling cambium is approached is not known. Do the hyphae penetrate the zone of resinous wood at the periphery of the stub and the encircling sleeve of resin deposited between the dead branch wood and the trunk wood, or, having become well established in the heart of the tree, does the fungus work back outside the stub, and gradually approach the cambium from the inside? It is significant that at least most primary infections seem to take place through branches which have been killed. One might then suspect an imperfect development of the resinous deposit in the wood of branch and stub which seems to be protective in function. But the common development of secondary *punk knots* indicates that once infection is established in the tree, the stubs of branches which have died naturally provide no certain barrier against the penetration of the fungus outwards. That the fungus is able to destroy ultimately the most resinous wood is clear from the examination of old *punk knots*, in which there is often an obvious connexion between the external *punk* in the bark and the rot in the bole. On the other hand, incipient rot begins in the heart before *punk knot* develops, though the period of time elapsing between the appearance of these successive symptoms, especially in the case of young trees, is relatively short. This period is indeterminable, and effectually prevents the precise determination of the time at which infection took place.

The tree studied was a rather branchy intermediate, 52 years old, as nearly as could be determined, and 5 inches in diameter at breast height. A well-developed *punk knot* was discovered 1 foot from the ground, and a 4-inch section of the trunk in which the knot was embedded was taken for examination. This section was cut along a radial plane to expose the knot throughout its whole length, the infection court, and the pith, as shown in Fig. 1.

The examination revealed that the tree had suffered the loss of the upper part of its stem when approximately 11 years old. At the point of injury, a foot from the ground, the stem was then $\frac{5}{8}$ inch in diameter and 5 years old. The breakage occurred just above a whorl of branches, and was fairly clean, although in the position of the embedded stub there were indications of sharp bending. One of the four branches immediately below had also been broken off at the same time, at a point $1\frac{1}{2}$ inches from the stem, and its stub was found completely embedded in the trunk, badly fractured, and sharply bent in a lateral direction. The other branches of the whorl had lived much longer, the largest, with a butt more than an inch across, having died only 8 or 10 years ago. As a result of the break, the stem died down to the crotch, and one of the laterals assumed dominance; the wound never healed. Before the short stub became callused over, it was infected by *Trametes pini*, and a *punk knot*

initiated. Its position in relation to the annual rings permits a close approximation of the age of the tree when infected.

The age of the tree, as determined by ring count at the ground, is 52 years. At the cut 1 foot above ground, just below the whorl above which infection

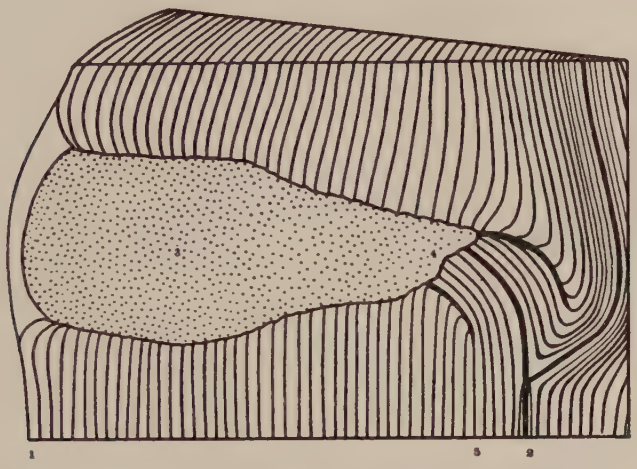

FIG. 1. 1. Outer wood surface of the trunk. 2. Pith. 3. *Punk knot.* 4. Face of broken leader (infection court). 5. Annual ring marking year in which injury occurred.

took place, the age is clearly 46 years, which gives 6 years for the seedling to reach a height of 1 foot—a not improbable period, under the circumstances. Ring counts of the broken leader and the broken lateral show plainly 5 years' growth, which means that the tree was 11 years old when injured. It is not possible to say exactly when the *punk knot* was initiated. It appears to have started somewhat earlier on one side of the stub than on the other. From ring counts inwards and outwards from the initial appearance of this symptom, we can say that at a minimum it began 5 years after the injury, and at a maximum 8 years. It follows that infection could have taken place no later. In fact it undoubtedly occurred somewhat earlier, according to the length of the indeterminable period of time elapsing between infection of the stub and the initiation of *punk knot* symptom. The tree, therefore, was somewhat less than 16 to 19 years old when infected.

THE FORESTRY SUB-SECTION OF THE BRITISH ASSOCIATION, ABERDEEN, 1934

DR. J. D. SUTHERLAND, C.B.E., was Chairman of the Department of Forestry, K*, and Dr. E. V. Laing, Secretary.

The following is a list of authors and titles of papers:

In conjunction with Section K, Botany:

'Some Aspects of Forest Biology', Professor A. W. Borthwick, O.B.E.

'Fungi and Forestry', Mr. J. Ramsbottom, O.B.E.

'The Preservation and Preparation of Timbers for Industrial Purposes', Mr. J. Bryan.

'General Willow Cultivation', Mr. Henry P. Hutchinson.

'Occurrence of Male Trees of *Salix alba*, var. *caerulea*', Dr. J. Burtt Davy.

'Forest Research Institute at Dehra Dun, India', Dr. R. Maclagan Gorrie.

'Town Planning with reference to general Amenity Planting', Lord Provost Henry Alexander.

'Tree-planting in Towns and Neighbourhood', Sir John Stirling Maxwell, Bt.

'Roadside Planting', Major S. Strang Steel.

'Amenity Planting and the Preservation of Natural Woodlands', Mr. W. Dallimore.

'Town Trees and Shrubs', Mr. W. B. Clark.

'Summation of Discussion on Tree-planting in Towns', Dr. J. D.Sutherland, C.B.E.

In conjunction with Sections K, Botany, and M. Agriculture:

'Introduction to a Discussion on Soil and Ecological Studies in relation to Forestry and Grazing', Dr. W. G. Ogg.

'Forest Soils', Dr. A. Muir.

'Peats and Peaty Soils', Dr. G. K. Fraser.

'Some Aspects of the Influence of Grazing on Vegetation', Mr. E. Wyllie-Fenton.

SOCIETY'S AND OTHER NEWS

SIXTH ANNUAL EXCURSION

The excursion was held from 23 to 26 May, with headquarters in London. On the 24th a visit was paid to the Royal Botanic Gardens, Kew, where a tour was made under the leadership of Mr. W. Dallimore. On the following day Rothamsted Experimental Station was visited, and Dr. Crowther, Dr. Keen, and Dr. Williams gave short lectures on the research work in progress in the chemistry, physics, and entomology sections, and a tour was made of the field experiments, including the long-period treatment of permanent grass, which is of considerable ecological as well as agricultural interest. On the last day Bedgebury was visited and a tour was made of the pinetum formed by the Forestry Commission and the Royal Botanic Gardens, Kew, and of the quarter-acre plots of a large number of tree species and races.

ELECTION OF OFFICE-BEARERS

As there is again no competition for any of the vacancies, there will be no ballot this year. All the office-bearers of this year will be re-elected at next Annual General Meeting, and the following will be the new members of Council in place of the three who retire by rotation at the close of this year: W. A. Robertson, F.R.G.S., Director of Forest Products Research; David Stewart, Inspector of Forestry, Northern Ireland; and John M. Murray, Assistant Forestry Commissioner for Scotland.

EIGHTH ANNUAL GENERAL MEETING

Place and date of next Annual General Meeting have not yet been fixed, but, in accordance with the new policy laid down at last Annual General Meeting, it will be held at some centre where it can be combined with a one-day excursion.

EXCURSION TO CONTINENT

As directed at last Annual General Meeting, the Council are making inquiries with a view to arranging for an excursion to some forestry centre on the Continent during the coming summer, but there is nothing definite to report yet.

APPOINTMENTS

Mr. J. D. Sutherland, C.B.E., LL.D., retired from the position of Assistant Forestry Commissioner for Scotland on 28 November 1934, and was appointed one of H.M. Forestry Commissioners. He was succeeded by Mr. J. M. Murray, B.Sc.

CORRECTION

In *Forestry*, viii (1), page 64, the spelling *coerulea* was used. This should have been *caerulea*.

REVIEWS

Die pflanzengeographisch-ökologischen Grundlagen des Waldbaus. Third Edition. Dr. Konrad Rubner. *Tharandt,* J. Neumann-Neudamm, 1934. 597 pages, 173 illustrations, and 8 maps. Price Rm. 32.

Review by R. Bourne

THE earlier editions of this important work have been completely re-written and greatly enlarged. The present edition purports to be a comprehensive treatise on the physiological, geographical, and ecological foundations of silvicultural practice in central Europe. It is divided into three parts, which may conveniently be entitled physiology, geography, and ecology. In the first, the climatic, edaphic, and geomorphological factors are separately considered. Reference is made to the most recent research on each subject and its significance explained. On the whole, the climatic factors are more adequately dealt with than the edaphic factors, but to students of tree physiology and silviculture this part should prove a most useful summary and is worthy of translation into English. In the second part, a sketch is given of the development of vegetation in central Europe in both prehistoric and historic times. The significance of the historical factor is thus clearly emphasized. The present distribution and racial differences of species are described, and the forest climaxes of Germany, Poland, Czechoslovakia, western Russia, Sweden, France, and Italy are indicated. This part is freely illustrated with small-scale maps, many of which are important contributions to knowledge, and should greatly help the student to view the silvicultural problems of these countries in perspective. In the third part a section is devoted to a discussion of the vegetative processes in virgin forest, and another to the significance of ground vegetation in the determination of forest types. Finally, the principal forest types of central Europe are shortly described. This is the least adequate part of the book, the fact that ecological survey has as yet played little part in the stocktaking of German forests being very apparent.

The avowed aim of the book is to accelerate the adoption, in Germany in particular, of the ecological approach to silviculture. It is pointed out that, although German foresters have tended in recent decades to pay closer attention to differences in local conditions, they have been slow to recognize that a full understanding of vegetative processes is essential, if their policy and practice is to be founded on a scientific and rational basis. This tardiness is attributed to the geographical position of the country, its topography, and the extent to which the natural vegetation has been disturbed by forest operations. The great advances made in the development of soil science in Russia, and in ecology in the northern countries of Europe, and in the alpine regions, are considered to be due to the peculiar conditions prevailing in such areas, and to the facilities locally existent for the study of natural vegetation. It is implied that the experimental methods of investigation hitherto relied on by German foresters should be preceded by ecological survey. The Finnish and Russian procedures are considered inapplicable to many parts of Germany, preference being given to the methods of such ecologists as Braun-Blanquet. Whatever the procedure adopted, however, the author is emphatic on the need for dividing a country into vegetative regions and sub-regions and drawing up silvicultural rules for each. In his opinion the past practice of attempting to apply a silvicultural system to large areas must generally be abandoned.

'Étude morphologique, anatomique, et systématique du genre *Picea*.' By Marcel Lacassagne. *Travaux du laboratoire forestier de Toulouse*, tome ii, vol. iii, article i, 1934, pp. 1–292; 650 text-figures.

Review by M. Y. Orr

THIS monograph, which is of the nature of a companion work to that of Viguié and Gaussen on the genus *Abies*, both emanating from the Forest Laboratory at Toulouse, deals exhaustively with the genus *Picea*, both from a morphological and a taxonomic standpoint, and comprises a history of the genus, a full description of each species, and a tentative natural classification of all the known spruce firs, together with a key for their identification. It is essentially a handbook for the expert, since the method of presentation demands a thorough knowledge of the finer distinctions employed to separate the species, while many of the forms enumerated are those not often met with in general practice. Altogether 43 species are described in the context, but the claims of several of these to specific rank are of doubtful value: the separation of *Picea heterolepis* from *Picea asperata*, or *Picea purpurea* from *Picea likiangensis*, because one happens to be pubescent and the other glabrous is splitting hairs in more senses than one.

The first part of the publication is taken up with a general discussion of the genus, which embodies many original observations, and this is followed by a series of detailed descriptions of every species, illustrated by some 650 sketches of their vegetative and reproductive organs. These pen-portraits have been compiled with meticulous care, and constitute perhaps the most useful section of the whole work. At the same time, the illustrations make it still more apparent that quite a number of these forms of spruce are not specifically distinct.

The latter part of the work contains a key to all the species, but in its construction the author has unhappily made use of certain fluctuating features as specific indicators, and this tends to lessen its value as a key. Most systematists will agree that the pubescence of the stem, the shape of the leaf-apex, and the number of resin-canals in the leaf are characters too variable to be used as separating factors for species of *Picea*. Incidentally the statement that resin-canals are entirely absent from the needles of *sitchensis*, *spinulosa*, and *Omorika* is obviously incorrect. The paper concludes with an ingenious and interesting attempt to portray the interrelationships of the various species, which is of its nature highly controversial. There is also an excellent bibliography.

As a monograph of the genus *Picea* this work is unique, and, despite some minor blemishes, it forms a valuable addition to the literature of the subject, although it may appeal more to the academic than to the practical mind.

'A Microscopical Study of the Structure of the Leaves of the genus *Pinus*.' By M. Sutherland. *Transactions of the New Zealand Institute*, vol. lxiii, 1934, pp. 517–68; plates liii and liv; 44 text-figures.

Review by M. Y. Orr

MISS SUTHERLAND has made a detailed study of the leaf-anatomy of 40 species of Pine in cultivation in New Zealand, the object of the investigation being to ascertain the possibility of utilizing their anatomical features for diagnostic purposes. The paper opens with a brief account of the technique employed in preparing the material for microscopic examination, but some of the methods are not to be recommended; this is followed by a description of a typical pine-leaf, illustrated by a photomicrograph of the transverse section. The relative value of the various leaf-tissues capable of being used as species-indicators is discussed, and the inadvisability of using

one factor alone is stressed. Out of this discussion there emerge certain 'fundamental characters', which are considered sufficiently constant within a species to be employed as discriminatory factors. These are the shape of the cross-section of a needle, the number and position of the resin-ducts and stomata, and the nature of the hypoderm. With the aid of these, a tentative key to the 40 species of Pine has been compiled. It is pointed out, however, that these so-called fundamental characters are not absolute, and the key should be used merely to provide confirmatory evidence in cases where the macroscopic features alone are insufficient to afford conclusive proof of identity. In a preface to this key a list of species is given in which the needle structure is said to differ from that described by other authorities, and it is suggested that the discrepancies may have arisen through the use of New Zealand-grown material. This is conceivable in the light of Larsen's researches on the influence of climatic factors on the leaf-anatomy of conifers, but, in the reviewer's opinion, the lack of uniformity is inevitable, having regard to the fluctuating character of the divergent features. The number of resin-ducts in a leaf may be comparatively constant in some species, while in others, e.g. *Montezumae*, *ponderosa*, *Thunbergii*, it does vary considerably, and to make universal use of such a feature as the *number* of ducts in the construction of a key is unwise. Incidentally, it is misleading to suggest that resin-ducts are wanting in the leaves of *Murrayana* (*P. contorta* var. *latifolia*) and *Pinea*. Furthermore, to group *aristata* with species the leaf-section of which is a sector, or to classify *monticola* as '4-sided', is equally incorrect. Apart from the key there is a useful series of descriptions of the leaf-anatomy of the various species, illustrated with photomicrographs, but the omission of the authority after the name of the species in every case is unfortunate as some of the names are synonyms. No bibliography is included in the work, and it is evident that Miss Sutherland is unaware of the recent researches on this subject carried out by Doi and Morikawa in Japan, and by Harlow in America, as their names are not mentioned in the context. The published papers of these authors both contain elaborate keys based on the needle structure of pines.

'Pienpuukysymys.' The Small Timber Problem. *Silva Fennica*, xxxi, 1933.

Review by the Editor

THIS publication in Finnish, with a summary in English, is the report of a Commission appointed by the Finnish Government to submit a scheme of research with a view to improving the sale of small timber, and developing the production and use of Finnish fuels.

An increase in the sale of small timber is one of Finland's most urgent forestry problems. It is emphasized that the increase in the yield and in the quality and size of large timber depends on adequate thinning, which in turn depends on the sale of the produce of such thinning. Further, waste timber in manufacture produces large quantities of small material.

The use of firewood has greatly decreased in Finland in recent years, due to the fall in price of imported coal. The export market for pit-props and Egyptian spars has also deteriorated. On the other hand, the pulpwood consumption has improved, but this only applies to spruce. The development of transport has tended to open up more districts from which small timber can be marketed.

As regards different species, the position of spruce is considered satisfactory, because of pulpwood utilization, and the problem is principally the increased utilization of small pine and birch.

The Commission makes various proposals of a general nature such as increased advertisement, and it also allocates the various researches considered necessary amongst existing institutions.

Reduction in production costs is of first importance, and attention is directed to improved tools and increased efficiency in transport. The first transport is generally by horse, and it is considered that methods of haulage can be improved. Thereafter, water transport is most important, and improvements in the binding together of small timber are necessary. The development of roads and railways in relation to forestry needs, and the reduction in railway freights, and in particular the adjustment of rates to quality of produce, are advocated.

It is considered that the development of the sulphate pulp industry would increase the consumption of small pine timber. At present it is organized in Finland, principally for sawmill waste, and the production is only one-third to one-quarter of what it is in Sweden. Further improvements in the sulphite process to use pine may be possible also.

Various methods of increasing the use of wood for fuel are considered. Particularly for birch, this is the only way of utilizing large quantities in the near future. The line of approach advocated is the instituting of research into methods of boiler construction in industrial plants to enable wood to be used economically, and a similar inquiry in respect of domestic heating appliances, particularly in relation to central heating. The increased use of firewood on the railways is also considered.

Attention is directed to the production of motor fuels from wood. In connexion with wood-gas or charcoal-gas as a substitute for petrol which has attracted attention in all countries that have no oil supplies, principally on the grounds of national defence, it is considered that there are many technical questions in the construction of generators to be settled, and grants for this research are proposed.

The production of wood-sugar by fermentation may be an important development. Wood-sugar produced by the *Bergius* process has been found useful as a food for pigs, 20 per cent. of a pig's food requirements being satisfied by such a food. It helped to produce a thin firm layer of fat.

The utilization of small timber from thinnings will become an important problem in state forestry in this country during the next decade. The conditions in Finland are entirely different from those in this country. There the timber industry is of first national importance, while the country is not developed industrially, and there are no supplies of coal. On the one hand our industrial development should make the problem less difficult, but on the other, national policy can never be moulded to aid forestry development as it can in Finland.

Nevertheless, the action that Finland is taking will be followed with interest by British foresters. The first steps taken are sound, namely a careful stocktaking, and the direction of research where there is a prospect of improvements in technique that would lead to greater consumption. Similar planning will be necessary in this country.

The Measurement of Standing Sample Trees. By H. G. Champion, M.A. Forest Research Institute, Dehra Dun. Forest Bulletin No. 82 (Silviculture Series). Delhi, 1934.

Review by James Macdonald

IN common with most other organizations which number permanent sample plot work among their activities, the Research Institute at Dehra Dun has come up against the difficulty of finding suitable sample trees in plots which have been under manage-

ment for a considerable period. The Silvicultural Conference held at Dehra Dun in 1929 recommended that 'the possibility of collecting some of the sample tree data from standing trees should be investigated', and this publication is the outcome of that recommendation.

Mr. Champion reviews most of the methods which are employed in research work in different countries. Some of these he has tested in India, while others he examined during a tour of the European Research Institutes in 1931, and after careful trials he has come to recommend with some modification the method developed by Schmied at the Austrian Forest Research Institute at Mariabrunn.

In this method, as modified in India, a light extension ladder is used for climbing into the crown of the sample tree from which a swing seat is lowered on pulleys, and all the measurements are made from this seat, which can be raised or lowered at will. The method thus differs from those which have been employed by the Swiss and Finnish Research Institutes where measurements are made by a man standing on the ladder. For the measurement of a single tree a party of 6 men appears to be necessary, 1 recorder, 1 calliper-man, 1 climber, and 3 labourers. The ladder is fixed to the tree by one of the men, who, when he has finished this task, comes down and allows the climber to ascend. From the top of the ladder, which can reach to 54 feet above ground, the climber goes up into the crown of the tree and fixes a light pulley to one of the branches. With this in position the ground staff pull up certain necessary articles, a staff for measuring the total height of the tree, a tape which may be 200 feet long, an 8-inch prong for determining the timber point, and a belt from which the swing seat is to be suspended. The total height of the tree is obtained by the climber, who ascends until the tip of the staff, which carries a flag and to which the measuring tape is tied, is level with the top of the tree. The height is read on the hanging tape by the recorders on the ground. The climber then finds out the timber height and ties the tape to the stem at that point; he then fixes the leather belt to the stem or to a stout branch and attaches thereto a differential pulley block which has been run up from the ground on the light pulley. The calliper-man in the swing seat is then pulled up from the ground and the measuring begins. While this is going on the climber remains in the tree and when the callipering has been completed he unfastens and sends down all the tackle. The timing of the various operations has been carefully tested and it is shown that trees of 130 feet in height can be fully measured in 74 minutes.

There are great advantages in this form of direct measurement as compared with the various forms of indirect measurement in use, but a glance at the remarkable photographs is sufficient to show that it is essential to have men who are used to climbing and who do not mind being swung rather precariously at considerable heights above ground. The size of the working party which is necessary is another point which must be borne in mind.

In a subsequent section Champion discusses various indirect measurements from the ground and describes his crown-meter, an ingenious official instrument for determining the limits of the crown spread. He also discusses the possible use of photographic and stereophotographic methods of measurement from the ground, and shows that the photographic method, at least, can be used with a good degree of accuracy.

This bulletin will be of great service to all engaged in scientific work on forest mensuration. It is written with the vigour and clearness which we have learned to expect from Mr. Champion, and it is illustrated by a number of really first-rate photographs which bring out the details of the operations in a very striking way.

Identification of the Timbers of Temperate North America. By S. J. Record. iv+196 pp. with 85 illustrations. Chapman & Hall, Ltd., London, 1934. Price 18*s.* 6*d.* net.

Review by L. Chalk

THIS book is of much wider interest than its title suggests, and is by no means merely a study of North American timbers. In form the book follows that of Professor Record's earlier work entitled *Identification of the Economic Woods of the United States*, and is separated into two parts, an introductory account of the anatomy and physical properties of wood, and a key to the timbers of North America. But the introductory part is so ably dealt with and is so general in scope that the book is likely to make its greatest appeal as a text-book on wood anatomy. It is of special interest as the first text-book to adopt the terminology proposed by the International Association of Wood Anatomists in its recently published *Glossary of Terms used in describing Woods.*

The book begins with an account of the broad botanical groups and their distribution and importance, which is followed by sections on the primary tissues and the origin and development of secondary tissues. A clear account is given of the different layers of the cell-wall—the intercellular layer, primary wall, middle lamella, &c.—the author regarding spiral thickening as a definite part of the secondary wall and not as a tertiary layer.

The section on pits is a great improvement on what is usually given in text-books on wood. The various types of bordered pits occurring in the hardwoods, which are so different in detail from those of softwoods, have at last been given an adequate description of their own, and such features as vestured pits (cribriform membranes) and primary pit fields (primordial pits) are clearly explained and illustrated. Professor Record's task in this matter, and in others, has undoubtedly been made much easier by the work of the Committee that prepared the glossary, but it is only fair to add that he himself was one of the most active members of that committee.

Each element and tissue is then described in turn, and the general aim of facilitating accurate identification is never lost sight of. The author not only gives an indication of the relative diagnostic value of the different features and the results of recent research, but also includes very useful lists of the families in which the most important features are to be found.

The subject of parenchyma affords a good example of the need for revision and standardization of the terminology and also of the difficulties involved. Complete agreement was not reached over the terms proposed in the glossary, but the provisional scheme of classification that was suggested has been adopted in this book and appears to have the merit of being comparatively easily understood and applied. Opinions may differ as to some of the individual terms, but if the scheme as a whole works in practice, much will have been accomplished.

This part of the book concludes with brief but adequate sections on storied structure, growth rings, texture grain and figure, colour and lustre, scent and taste, density and specific gravity, and anomalous structure.

Part II, 'The Timbers of Temperate North America', is definitely more local in character, though the key to the woods, which is based primarily on macroscopic features, but includes supplementary microscopic details, should prove useful to wood anatomists generally. The key is followed by a very useful collection of notes and references for each species or commercial group. These notes are concerned mainly with the distribution of the tree and the character, uses, and supplies of the timber,

and will be found particularly helpful where several species are grouped under one commercial name, as for example pitch pine.

Comparatively little is said about the origin and development of the various tissues, and the author appears to have limited the scope of the book to what can be seen and described in a piece of wood, and to have deliberately avoided the more theoretical aspects of the subject. The book gives the best descriptive account of wood anatomy that has yet appeared and will be of great value to both students and research workers. The illustrations, both drawings and photomicrographs, are exceptionally well chosen and add very considerably to the interest of the book.

'The Beech Bark Disease. A *Nectria* disease of *Fagus*, following *Cryptococcus fagi* (Baer.).' By JOHN EHRLICH. *Canadian Journal of Research*, vol. x, Special Number, June 1934.

Review by T. R. PEACE

THE Beech Coccus, *Cryptococcus fagi*, has long been known as a common insect pest, and has in the past obtained what is probably an undeserved reputation as a cause of damage to beech in Europe. In the paper here considered this insect is proved to be the necessary predisposing factor to a serious beech disease in North America, the actual cause of which however is fungal. The fungus, a *Nectria* species closely resembling but not quite identical with *Nectria coccinea* (Pers.) Fries, enters the bark of the tree through the small patches of dead tissue surrounding the stylet punctures of the insect, and causes the death of large patches of the bark and eventually of the whole tree.

Both the insect and the fungus would appear to be new to North America, and to have spread from the neighbourhood of Halifax, Nova Scotia. The former now has a rather wider distribution than the latter, which is found only in Nova Scotia, in parts of New Brunswick, and in a few localities in Maine. The disease is chiefly on *Fagus grandifolia* Ehrh., the forest beech of North America, but also occurs on *F. silvatica* L. In all the areas where it is found the percentage of beeches attacked is very high, about 90 per cent., and the percentage dead varies from 20 to 50 per cent., according to the period which has elapsed since the attack commenced. In view of the serious nature of the disease it is a relief to read, 'Personal observations and consultations with forest entomologists and pathologists in England during the autumn of 1933 have convinced the author that *Cryptococcus fagi* is widespread, that parasitic fungi do not here ordinarily follow infestation by the insect, and that no damage can be attributed to the woolly beech scale or to associated fungi in England'. It is to be hoped that energetic measures will be taken not only to retard its spread in North America, but also to prevent its introduction into other countries. For, although the author refers to reports of damage following *Cryptococcus* infestation on the continent of Europe as if they were identical with the North American disease, there would appear to be no evidence to support this. They are not at any rate of so serious a nature.

The paper contains a very full account of the history, nomenclature, and habits of the insect, a description of the fungus, and very complete observations on the pathology, severity, and extent of the disease. Experiments designed to prove the pathogenicity of the fungus and the subsidiary but necessary role of the insect are as satisfactory as could be expected, considering the difficulties attached to them, and amply sufficient when supported by the field observations. An indication of correlations between the severity of the disease and certain physiographic factors, and also with the diameter of the individual tree, was found. For ornamental trees control by spraying against the

insect is practicable; for forest stands only general sanitary measures appear to be possible, though the use of parasites is suggested as a possible line for future investigations on control. It is to be hoped that the work will be continued so that it may be possible to finish a very thorough investigation by the publication of more complete measures for control. The paper is well and fully illustrated, and has a bibliography of 143 titles, many of them only concerned, however, with the nomenclature of the insect.

Forestry in Ireland. By JOHN MACKAY. Cork University Press, 1934. Price 5*s*.

Review by DAVID STEWART

MR. J. MACKAY makes a plea for a greatly extended programme of afforestation in the Irish Free State. He affirms that the planting of 2,000,000 acres is necessary for proper land utilization, and to afford to agriculture the industrial support necessary for national economic stability.

He stresses the need for an agronomical survey of the country to show the extent of suitable land available for afforestation, and quotes evidence to show that as an addition to the existing area of 230,000 acres of what he terms non-forest woodlands, 1,814,000 acres of grazed mountain and 176,000 acres of drained marsh can readily be made available. To aid in acquiring this area, he proposes that the forest authority should have powers of compulsory purchase, but makes the task more difficult by ruling out purchases from the 1,800,000 acres of sub-marginal tillage and pasture lands together with all peat projects, and still further restricts the suitable site area available by proposing the planting of Douglas fir and Sitka spruce to the exclusion of other species including *Pinus silvestris*.

The total area of grazed mountain, barren mountain, and marsh from which the 2,000,000 acres are to be obtained is 2,942,080, and the area of land acquired to date by the forestry branch is 50,598 acres of which 34,788 are plantable. It would, therefore, provided the percentage of plantable land is the same, be necessary to acquire the entire 2,942,080 acres to obtain 2,000,000 acres of plantable land. The land already acquired having been selected from a large number of properties offered to the forestry branch, many of which were turned down as entirely unsuitable, it is not to be expected that over the whole area of mountain and marsh the percentage of plantable land would be as high as for this selected area. Not only is this so, but the acquired area includes 2,000 acres of old woodland, and an unknown but fairly large area of sub-marginal tillage and pasture land, not to mention peat projects. Of two forest areas mentioned Camolin was practically all either old woodland or tillage and pasture lands, while Baunreagh, a typical mountain area, in addition to a considerable area of sub-marginal tillage and pasture, has a very high percentage of unplantable land. A very considerable portion of the lands now held are in County Wicklow, where the percentage of the waste land which is plantable is relatively high as compared with Donegal, Mayo, and Kerry counties, which have an even higher percentage of waste to other lands, but of which very little can be classed as plantable.

Writing of the six north-eastern counties he states that except for north Tyrone, Armagh, and the hill country of Down, the area of afforestable land in the six counties is inconsiderable. This statement is misleading as counties Londonderry and Antrim have as high a percentage of plantable land as north Tyrone or south Down, and higher than County Armagh, where it would be difficult to find any area of a size suitable for state forestry if sub-marginal tillage and pasture are excluded.

In chapter eight, dealing with finance, the cost of land purchase is put at £2 10*s*. per

acre, it being stated that the average price paid by the Forestry Commission up to 1924 was £1 16*s.* 3*d.* per acre. In the tenth annual report, however, it is stated that the average price paid for *plantable* land was £3 5*s.* 9*d.* per acre.

On page 94 the employment which would be given in felling the annual cut of 50,000 acres of Douglas fir and Sitka spruce, estimated to yield 6,467 and 6,660 cubic feet per acre, is estimated at 1,000 men or one-fifth of the number to be found employment replanting the same area. Second quality Sitka spruce at 40 years gives some 350 trees per acre. Fifty thousand acres to 1,000 men gives 50 acres per man, so that each man working 312 days per annum will have to fell 56 trees per day (over 1,000 cubic feet of timber), surely an impossible task.

A further financial calculation is based on an output of saw timber per man of 1,978 cubic feet per annum. The wage proposed to be paid for this class of work is £3 10*s.* per week, which makes the cost of conversion over 1*s.* 10*d.* per cubic foot for timber which is to be sold at 2*s.* and 3*s.* per cubic foot.

Theory and Practice of Silviculture. By Frederick S. Baker. McGraw-Hill Book Company, London, 1934. Price 30*s.*

Review by the Editor

THIS is a volume in the new American Forestry Series that is under the general editorship of Walter Mulford. The author is Associate Professor of Forestry in the University of California. This is a general text-book on silviculture, in the sense that it deals broadly with the subject, including both its biological basis and practice. The author does not claim that it is comprehensive, however, the aim being to include only what is generally applicable throughout the United States of America. For example, artificial regeneration is not dealt with, which decreases its value as a general text-book in this country.

The book is, however, interesting because of its method of approach, which is physiological. This is sound, but curiously enough soil is only dealt with incidentally. It appears to the reviewer that the logical method of developing this means of approach is physiology, soil science, ecology, practice.

The book is divided into five parts. Part I deals with plant physiology, using data for trees as far as these are available. There are chapters on: forest genetics, the water cycle, the carbon cycle, the nitrogen and mineral cycles, growth of trees, reproduction of the forest, and injury, disease, and death of forest trees. This section brings much interesting matter together in a convenient form, but it is at least open to doubt whether the treatment can be considered adequate without reference to other literature. It is remarkable to find no reference to Lundegårdh, who dealt so interestingly with physiological plant ecology in *Klima und Boden in ihrer Wirkung auf das Pflanzenleben.*

Part II deals with forest ecology, the subjects included being—forest types and sites, form and composition of stands, density of stands, tolerance, the theory of succession, and crown classification. While these subjects deal with trees in their relationships one with another, and with their environment, the treatment is not markedly from an ecological angle.

Part III is called 'Systematized silvicultural experience'. As already stated, it does not deal with artificial regeneration. As little over 100 pages are allotted, it will be clear that the treatment of systems of silviculture and tending are not detailed, particularly on their practical aspects. There is, however, emphasis on the physiological basis of systems of silviculture which is to be welcomed. Owing no doubt to their inapplicability

to American conditions, European systems of thinning are only dealt with in outline. It is curious to find Heck's methods being taken second hand from Martin's *Die geschichtliche Methode in der Forstwirtschaft*, when Heck described them himself recently.

The remaining parts deal with field studies in silviculture, and applied silviculture. The latter deals with the chief forest regions in the United States.

The book is to be welcomed because of its emphasis on the physiological basis of silviculture. The field attempted is, however, too extensive to enable adequate treatment to be made of its different sections. Silviculture, in its broadest sense, is now too large to be dealt with in one book by one man.

NOTICES

Fourteenth Annual Report of the Forestry Commissioners for the year ending September 30th, 1933. H.M. Stationery Office, Adastral House, Kingsway, London, W.C. 2. 1934. Price 9*d*.

THE report follows the usual lines, giving information regarding the work done, and expenditure under the various heads of account. The area acquired during the year was 17,591 acres, of which 15,335 acres were classified as plantable. Excluding the Crown woodlands, 726,599 acres have been acquired to date by purchase, lease, or feu, of which 455,220 acres are classified as plantable. The area planted to date is 232,711 acres.

The principal point of general interest in the report is the information regarding the effect of the 1933 drought. The deficiency in rainfall was general, Scotland as well as England and Wales sharing in it. The rainfall was under 70 per cent. of normal in many parts of the country, and the average did not exceed 81 per cent. New plantations on the clay soils of the south-east of England suffered from the drying and cracking of the soil, while turf-planting was not so successful as usual. On the other hand, planting after preparation by ploughing was satisfactory, and direct sowing of acorns was not adversely affected.

Another influence of the dry season was the greatly increased number of fires, namely 623, destroying 1,313 acres, valued at £22,670. This, however, compared favourably with the last drought year—1928–9—when there were 409 fires, destroying 4,574 acres, valued at £45,961.

Report of the Forest Products Research Board, with the Report of the Director of Forest Products Research for the year 1933. H.M. Stationery Office, Adastral House, Kingsway, London, W.C. 2. 1934. Price 1*s*. 3*d*.

THE report follows the usual lines, describing the work in progress in the different sections into which the laboratory is organized. Further work was done on the relation of the moisture content of wood and the surrounding hygrometric conditions, to determine what takes place under service conditions. Temporary heating in a new building renders it more suitable for the installation of seasoned timber. Further work on air-seasoning indicated that the optimum width of pile was 6 feet, but such piles need only be separated by a narrow opening of, say, 12 inches. Air movements in timber piles bear little relation to the direction of the prevailing wind. Investigations are in progress on the influence of Black Heart in ash. Improvements were made in the optical and mechanical methods of assessing quality of machine finish. Work was continued on *Lyctus* attack, the Death-watch beetle, and the Pin-hole borers; while in

the Mycology Section further work was done on Dry Rot and other wood-destroying fungi. Considerable progress is recorded in the study of the chemistry of decay in wood. Advisory work greatly increased during the year, and this is a tribute to the importance of the work done by the Laboratory.

Report of the Committee on the Mechanical Testing of Timber. H.M. Stationery Office, Adastral House, Kingsway, London, W.C. 2. 1934. Price 1*s.*

IT has been found that the methods of mechanical testing of timber adopted as standard were not entirely satisfactory, and in 1929 a committee under the chairmanship of Sir Alfred Ewing was formed to investigate the matter. This is their report. It deals in detail with methods to test tension along the grain, tension perpendicular to the grain and 'cleavage' test, compression along the grain, compression perpendicular to the grain, shearing along the grain, static bending tests, impact bending tests, notched-bar tests, hardness, and abrasion.

The Imperial Forestry Institute, University of Oxford, Tenth Annual Report, 1933–4.

THE report outlines the work in progress. Twenty-one students attended courses of study. The regional survey of the area between the Chilterns and the New Forest was continued; this has demonstrated the correlation of agricultural practice and the woodland vegetation with soil. The identification of botanical specimens was continued and research done on black Italian poplars and their hybrids, and the systematy of the cricket bat willows and elms. Various researches are in progress on the structure and properties of wood including the systematic anatomy of the dicotyledons. Work was continued on frost damage, elm disease, *Phytophthora* disease of beech and chestnut, *Meria laricis*, and poplar canker. The investigations were continued on the Pine-shoot Tortrix Moth, the Green Oak Tortrix Moth, Chafer beetles, and Pine-shoot beetle. Instructional courses were given in forest engineering.

Journal of the British Wood Preserving Association, vol. iv, 1934. Price 7*s.* 6*d.*

THIS volume prints the lectures with discussions delivered during last winter. They were: 'Wood preservation in the service of the Post Office', by Mr. R. G. Bennett; 'Development of disease in the living tree', by Mr. W. R. Day; 'The use of treated timber in railway stock construction', by Mr. W. H. Brown; 'Coal-tar creosote oil as a wood preservative', by Mr. N. A. Richardson; and 'Timber buildings', by Mr. O'Hea. The volume also contains contributions on: 'Creosoted Douglas fir round piling', by Mr. Herrman; 'Wood preservation', a broadcast talk by the Secretary (Mr. R. C. B. Gardner); and 'A note on an experimental fence at Knaphill, and the butt treatment of fence posts', also by the Secretary.

The Physiography and Vegetation of Trinidad and Tobago. By R. C. MARSHALL. Oxford Forestry Memoirs, No. 17, 1934. The Clarendon Press, Oxford. Price 6*s.*

IN Part I a description is given of the history, topography, geology, soils, and climate of the two islands. In Part II the forest vegetation is classified and described. The data on which this is based were obtained by the method of strip survey, 16,000 chains of 1 chain strip being traversed during the past few years as part of the routine departmental work. It would have been interesting if more information had been given on

the application of the method of strip survey, for example the alinement and spacing of the strips. The two broad forest types are Tropical Rain Forest, and Tropical Semi-Deciduous Forest; the former is subdivided ecologically into climax associations, edaphic climax units, and secondary vegetation. There is a further classification on a floristic basis. More work will be necessary before the relationship between the different communities can be elucidated and their status as seral or climax stages defined, but it would appear that, in the absence of interference, *Mora excelsa*, a shadebearer which reproduces itself abundantly, would dominate the mixed rain forest. A point of general interest is that oysters grow attached to the roots of trees in the Mangrove swamps, and are eaten all the year round. There are numerous illustrations.

Silviculture of the Mixed Deciduous Forests of Nigeria. By W. D. MacGregor. Oxford Forestry Memoirs, No. 18, 1934. The Clarendon Press, Oxford. Price 15*s*.

THIS publication is the first-fruits of the decision made some years ago to form a specific silvicultural research branch in the Nigerian Forest Service. The forests to which the work relates contain deciduous trees on the upper canopies and evergreens in the lower canopies; this type merges into the evergreen forest in the south, and into the deciduous forest in the north. The principal natural orders in it are: Sterculiaceae, Leguminosae, Moraceae, and Combretaceae. The type requires a rainfall of 50–70 inches per annum.

Firstly, the results obtained to date are presented for 12 permanent sample plots established in recent years in plantations, 5 of which relate to teak, the remainder being of indigenous species. Methods of tree classification worked out for temperate conditions in Europe have been applied, and their successful application to tropical species is of interest. The crops are too young and the plots too recent to give other than preliminary data. Height growth is very fast, 75 feet being reached in 17 years by teak, but the volumes are less spectacular. Secondly, some growth data are given for the natural forests.

The third section of the memoir gives the results obtained from the application of experimental methods to problems of nursery treatment, formation of plantations, and natural regeneration. This was pioneer work, and it is recognized that it would have been unwise to attempt other than simple methods at the outset, but it is to be hoped that as the work develops, modern technique will be followed, with suitable replication, and statistical analysis of the results, because it is of the first importance that the data on which tropical silviculture is to be based should be well founded.

The next section is devoted to a description of the silvicultural characteristics of the principal indigenous and introduced species in the south-western provinces. The data presented comes partly from observation and partly from experiment. Finally, there are drawings and descriptions of the seed and seedling stages of over 20 species.

There are a large number of plates and text-figures. Mr. MacGregor is to be congratulated on obtaining and bringing together a large amount of data which should be of definite value to the region to which it applies.

Imperial Bureau of Plant Genetics, *Plant Breeding Abstracts.*

THE attention of foresters is directed to the above. There is a section in each issue devoted to forestry, and the references are principally from publications not ordinarily seen by foresters. In vol. iv, No. 4, there is an abstract of C. S. Larsen's paper on

'Forest Tree Breeding' in the *Yearbook of the Royal Veterinary and Agricultural College*, Copenhagen, 1934, 93–113; and in vol. v, No. 1, one of an article by I. Nikitin on 'The influence of X-rays on the pollen of trees and herbaceous plants' in *Sovietskaja Botanika*, 1934, No. 1, 66–74. There are also abstracts of papers on the chromosome numbers of *Ulmus*.

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